ARS-BLM COOPERATIVE STUDIES

REYNOLDS CREEK WATERSHED

Northwest Watershed Research Center
Western Region
Agricultural Research Service
U. S. Department of Agriculture
Boise, Idaho

INTERIM REPORT NO. 5
Cooperative Agreement No. 14-11-0001-4162(N)

For Period January 1, 1974 to December 31, 1974

TO

Denver Service Center
Bureau of Land Management
U. S. Department of the Interior
Denver, Colorado

MARCH 1975

(NOTE: Generally, a variety of watershed data are compiled on a calendar year basis. However, the water year, beginning October 1 and ending September 30, has proven best for hydrologic comparisons.)

INTRODUCTION

Cooperative watershed research between the Agricultural Research Service, U. S. Department of Agriculture, and the Bureau of Land Management, U. S. Department of the Interior, was initiated in 1968 under Cooperative Agreement No. 14-11-0001-4162(N). Also, the Memorandum of Understanding, dated July 6, 1961, which is a part of the Cooperative Agreement, specifies the overall responsibility of each agency.

This interim report summarizes progress and results from January 1 through December 31, 1974, as outlined in the work plan for F.Y. 1975. The report also describes the proposed activities and changes in objectives for consideration in the F.Y. 1976 work plan.

Data collection, processing, and analysis continued according to the F.Y. 1975 work plan and details of progress and accomplishments are described in each section of the report. Further information is contained in Northwest Watershed Research Center Annual Reports for 1972 and prior years and in Interim Report Nos. 1, 2, 3, and 4 of ARS-BLM studies in the Reynolds Creek Watershed under Cooperative Agreement No. 14-11-0001-4162(N).

The appendix materials are research results which C. L. Hanson completed this past year. He conducted the field and initial analysis while stationed in South Dakota.

The Northwest Watershed Research Center is an element of the Utah-Idaho-Montana Area Office, Western Region, ARS, USDA. Its research program serves the Owyhee Plateau Area of the Columbia River Basin and similar Soil Conservation Problem Area in the Northwest. Research needs of greatest urgency in the region are precipitation-runoff relationships, snow distribution and melt, sedimentation, channel stability, erosion prediction and control, optimum management practices for rangeland, and conservation of water quality. Its present field program is centered in the Reynolds Creek Watershed located 55 miles Southwest of Boise.

The mission of the Northwest Watershed Research Center, in response to the needs of the region, is to conduct research with the following objectives:

1. Develop techniques for inventorying snow accumulation, distribution, and water equivalent of continuous and isolated snowpacks. Determine the factors affecting timing and rates of snowmelt and formulate alternative procedures for predicting or forecasting runoff from melting snow, rainfall, or both, where the ground may or may not be frozen.

TABLE OF CONTENTS

2. Formulate and test rangeland watershed models which interface models for precipitation, snowmelt, infiltration, ET, subsurface flow, and surface flow, for predicting or forecasting streamflow, water yield, and/or water balances.

3. Derive and test models for prediction of rangeland erosion, channel degradation and/or aggradation, and downstream sediment yield.

4. Develop water quality models for rangeland watersheds that combine runoff models, erosion and sediment yield models, and rangeland management models, which predict water quality parameters for in-stream and off-stream uses.

5. Establish the effects of rangeland management systems on soils and range conditions and productivity.

STAFF

Aaron, Virginia M.	Hydrologic Aid (Perm., 35 hr/wk)
Brakensiek, Donald L.	Research Hydraulic Engineer (LL & RL)
Burgess, Michael D.	Electronic Technician (Perm., 39 hr/wk)
Butler, Donna M.	Supervisory Administrative Clerk
Coon, Delbert L.	Hydrologic Technician
Cox, Lloyd M.	Hydrologist
Engelbert, Carrol D.	Hydrologic Technician
Engleman, Roger L.	Hydrologic Technician
Gidley, Jess R.	Hydrologic Aid (Temp., 16 hr/wk)
Hanson, Clayton L.	Agricultural Engineer
Hermann, Ralph F.	Carpenter
Hoagland, Roy M.	Automotive Mechanic
Johnson, Clifton W.	Research Hydraulic Engineer
Morris, Ronald P.	Hydrologic Technician (Perm., 35 hr/wk)
Perkins, Lee	Hydrologic Technician
Robertson, David C.	Hydrologic Technician
Schumaker, Gilbert A.	Soil Scientist
Smith, Rona G.	Clerk Typist (Temp., 16 hr/wk)
Stephenson, Gordon R.	Geologist
Trautman, Kenneth W.	Engineering Equipment Operator
Wilson, Glenna A.	Procurement Clerk
Zuzel, John F.	Hydrologic Technician

PRECIPITATION

Title: Precipitation characteristics of a northern, mountainous semiarid watershed.

Personnel Involved:

J. F. Zuzel, Hydrol. Tech.	Supervise data collections and conduct special analyses requiring the use of a computer.

Date of Initiation: June 1961

Expected Termination Date: Continuing

INTRODUCTION

No dense, recording rain gage network existed in the Northwest prior to establishment of the Northwest Watershed Research Center. Such a network is necessary to delineate thunderstorms and storm variability. National Weather Service data collection stations are generally located in or near the main cities. Since these are generally along the main stems of major streams or in valleys, a sampling of precipitation on the range watershed areas is not available from their records. Also, there are too few rain gages capable of recording intensities or even individual storm data.

Objectives:

1. To develop and compute parameters that characterize precipitation rates and amounts for application to runoff and erosion predictions.

2. To establish general precipitation-elevation-aspect-slope-relationships from precipitation data obtained in the Reynolds Creek Experimental Watershed for hydrologic and forage production forecasting.

3. To develop depth-duration-frequency and depth-area-duration relationships for the Reynolds Creek Experimental Watershed for application to similar rangeland areas.

4. To formulate and test methods that predict precipitation inputs to hydrologic models for the Reynolds Creek and similar rangeland areas.

PROGRESS

Precipitation data collection was continued from the rain gage network in the Reynolds Creek Watershed (Figure 1), comprised of 49 dual-gage sites (98 gages). Using the dual-gage model, computer programs were used to convert shielded and unshielded precipitation data to actual precipitation for all stations for the years 1968-1973. Data processing for the 1962-1967 precipitation network is progressing. Regression models, stratified by elevation zones and season, were developed and will be used to correct precipitation data prior to 1968 from 5 foot unshielded values to actual precipitation. Completion of this processing will provide a continuous record for the precipitation network from 1962 to date.

A precipitation intensity program was used to compute storm intensities for all dual-gage sites for the years 1968-1973. For the purposes of this program a storm is defined as a precipitation accumulation of 0.25 inches or greater and where periods of no precipitation are less than 4 hours. The program output consists of 5, 10, 15, 20, and 30-minute intensities, and 1, 2, 4, 6, 12, and 24-hour intensities for each storm. In addition, the program outputs the maximum intensity for each time period.

A precipitation duration and intensity analysis was conducted using data from the Rabbit Creek precipitation network. Distinct seasonal differences in both storm duration and storm intensity were observed. Generally, storms occurring during the October-March period are of longer duration and lower intensity than storms occurring during the April-September period. Results are presented in the Rabbit Creek Report.

A study of between-site correlation of daily precipitation for the years 1968-1973 was initiated.

A precipitation network was established in cooperation with the Idaho Department of Water Resources on the Silver Creek Watershed near Hailey, Idaho. Data analysis will utilize procedures developed in the Reynolds Creek Experimental Watershed.

SIGNIFICANT FINDINGS

The completion of maximum intensity data for all dual gage sites is considered a major step in attaining the stated objectives. Table 1 summarizes six years of maximum intensity data for precipitation site 049X61 located at the Summit Runoff Plot. This is an example of the type of data which has been computed for each dual gage site.

Results of the precipitation duration and intensity analysis on the Rabbit Creek precipitation network are presented in the Rabbit Creek Report.

TABLE 1.--Maximum intensities at Site 049X61 for the years 1968 through 1973.

Time Period	Maximum Intensity (Inches/Hour)						
	1968	1969	1970	1971	1972	1973	All Years
5 min.	2.16	2.64	2.63	2.52	2.26	1.24	2.64 (1969)
10 min.	1.98	2.58	1.96	2.22	1.85	1.24	2.58 (1969)
15 min.	0.86	1.95	1.57	1.62	1.30	0.84	1.95 (1969)
20 min.	0.72	1.63	1.19	1.32	1.03	0.64	1.63 (1969)
30 min.	0.67	1.39	0.82	1.03	0.75	0.44	1.39 (1969)
1 hr.	0.63	0.87	0.24	0.59	0.42	0.33	0.87 (1969)
2 hr.	0.37	0.48	0.20	0.30	0.25	0.27	0.48 (1969)
4 hr.	0.19	0.29	0.12	0.15	0.18	0.24	0.29 (1969)
6 hr.	0.14	0.16	0.06	0.13	0.13	0.21	0.21 (1973)
12 hr.	0.10	0.07	0.05	0.07	0.07	0.13	0.13 (1973)
24 hr.	0.00	0.00	0.00	0.04	0.00	0.00	0.04 (1971)

WORK PLAN FOR FY 76

Stochastic modeling describing temporal and spatial variations of precipitation will be developed and tested for input to watershed hydrologic models.

Between-site correlations of daily precipitation amounts will be calculated and used to assess the spatial variability of daily precipitation and possible network size reduction will be investigated.

Precipitation parameters will be developed for application to erosion and sediment yield prediction, runoff prediction, and forage yield forecasts.

REPORTS AND PUBLICATIONS

Rawls, W. J., D. C. Robertson, J. F. Zuzel, and W. R. Hamon 1974
Comparison of precipitation gage catches with a modified alter and a rigid type windshield. Accepted for publication in Water Resources Research, October 22.

Johnson, C. W., L. M. Cox, W. J. Rawls, G. R. Stephenson, and J. F. Zuzel 1974
Instrumentation for hydrologic research on the Reynolds Creek Experimental Watershed. Accepted for publication in Proceedings IWRA International Exposition and Seminar on water resources instrumentation, June 25.

Northwest Watershed Research Center, Agricultural Research Service, USDA 1974
Hydrology of Rabbit Creek Watersheds, Owyhee County, Idaho, 1968-73. Final Report on Frail Land Studies for the Bureau of Land Management, U. S. Department of Interior, July.

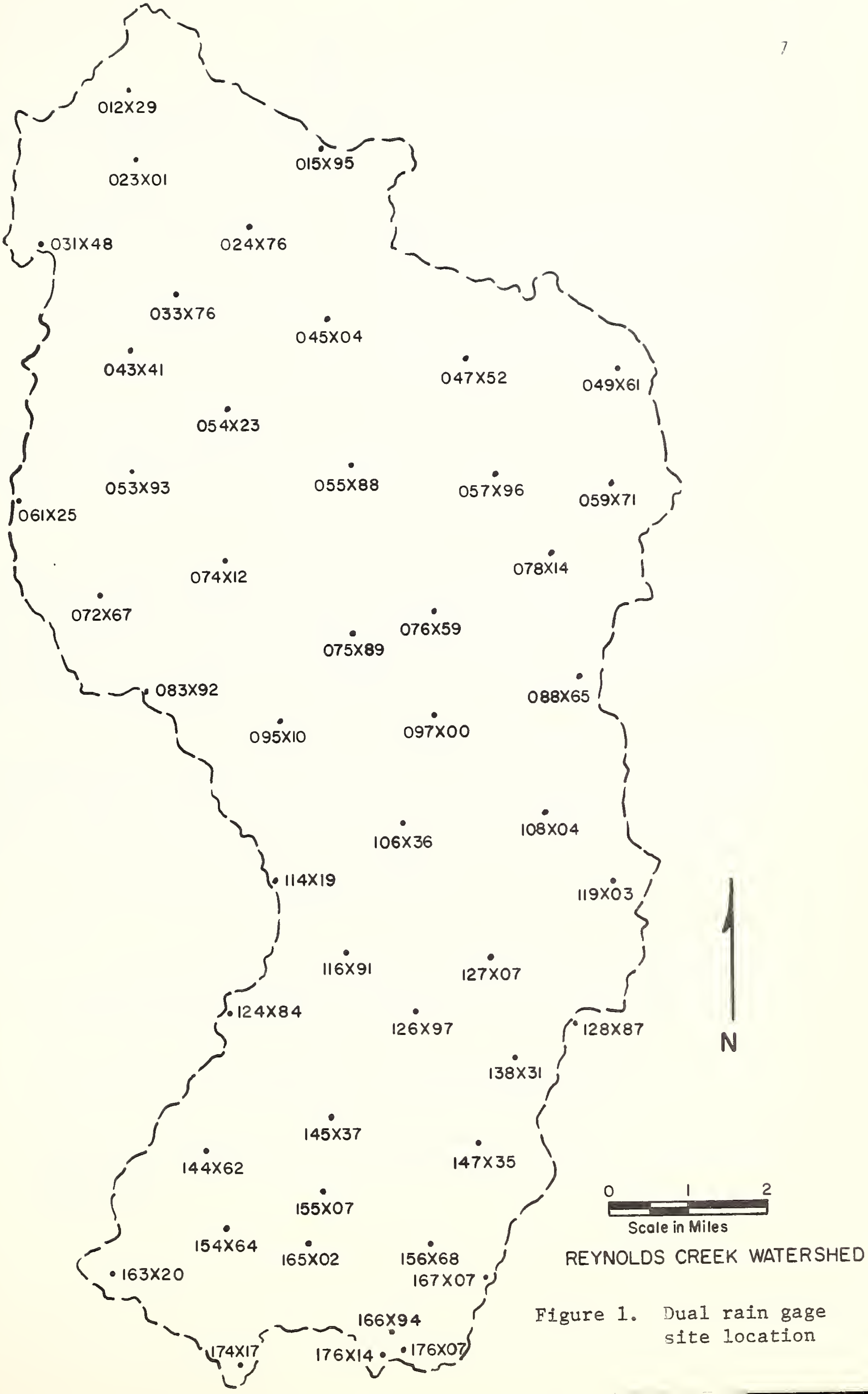

Figure 1. Dual rain gage site location

SNOW

Title: Snow accumulation, snow redistribution, and snowmelt

Personnel Involved:

L. M. Cox, Hydrologist	Supervise the planning, designing, execution, analyzing, and reporting of proposed experiments.
J. F. Zuzel, Hydrol. Tech.	Assist in the planning, designing, execution, analyzing, and reporting of proposed experiments.

Date of Initiation: 1961

Expected Termination Date: Continuing

INTRODUCTION

A substantial proportion of the runoff from the western rangelands has its origin in rapid melting snow. To improve the quantity or timing of flow from snow-fed streams by manipulation of vegetation or by other practices requires that the behavior of snow be well understood. There has been little research on the behavior of snow in shrub areas anywhere--and almost none in the sagebrush areas of the Northwest.

Destructive late winter and spring floods in the Northwest frequently originate from rapid melting snow at low elevations characteristic of the sagebrush zone. Although there is little likelihood of modifying snowmelt rates enough to alleviate this threat, knowledge about the behavior of snow in the sagebrush zone will be helpful in devising better warning and forecasting techniques that may reduce the danger to life and property from snowmelt floods.

Objectives:

1. To determine the physical and meteorological factors contributing to nonuniformity of snow accumulation in shrub-covered study basins on mountainous terrain.

2. To determine the influence of the controlling physical and meteorological factors on snowmelt from the above areas.

3. To improve snowmelt prediction techniques by evaluating the energy exchange process of the snow surface under different snow cover conditions.

4. To study the oasis effect of isolated, late-lying snowdrifts for potential management that minimizes evaporative losses and maximizes and prolongs water yield from snowmelt.

PROGRESS

Exceptionally high snow ablation rates were measured on an isolated late-lying snowdrift during May and June (Figure 1). Unseasonably high average daily air temperatures (16°C) were recorded at this 2072 m elevation during late May and June and, thus contributed to this high ablation rate. For one 9-day period during the latter part of June, 7.1 cm of water was melted and 3.3 cm were evaporated for a total loss of 10.4 cm/day. Energy exchange measurements showed that 54 percent of the energy available for ablation came from sensible heat transfer and 46 percent from radiant heat. This is contrasted to continuous snow cover conditions where practically all of the energy comes from radiant heat transfer. Drift profile studies showed that the top of the drift surface ablated 23 percent faster than the more abrupt face (Figure 2).

A trial planting of Monterey Knob Cone Pine trees was made in April to test the possibility of using natural vegetation for snow management purposes. Two hundred trees were planted in two rows, 2 feet apart at the toe of an existing snowdrift in the center of a mile long drift area. Approximately 55 percent of the trees have survived to date.

A long-term water supply forecast model, using parameter optimization techniques on snow course data, was found to be superior to all other models currently used on the Boise River Drainage. The Idaho Department of Water Resources recommended this model for forecasting Boise River water supplies.

Analysis of the accuracy for predicting the areal distribution of snow and snow-water content by photogrammetric procedures was continued. Study of photogrammetric snow measurements on the Reynolds Mountain Study Basin indicate that grid spacing could be increased from 25 feet to 100 feet and 325 feet with a loss of accuracy in total volume of snow of only 2.5 percent and 10 percent, respectively. The above change in grid spacing enabled the number of points processed to be decreased by 94 and 99 percent, respectively. Preliminary evaluation of snow density on a watershed indicated that density varies according to aspect and drift locations. The drift locations usually had a 10 percent greater density than the other area.

SIGNIFICANT FINDINGS

The oasis effect of late-lying snowdrifts is conducive to producing high evaporative losses during late season snowmelt periods. Late June measurements showed that at least 54 percent of the available energy came from sensible heat transfer which helped to evaporate 3.3 cm of water per day from the snow surface during one 9-day period.

The photogrammetric method for measuring snow accumulation on sagebrush rangelands can be made more feasible by increasing grid spacing of ground points.

WORK PLAN FOR FY 76

The energy exchange process will be evaluated by comparing data from meteorological parameters, independent measurements of energy balance components, and melt collectors. The data were obtained during FY 75 on isolated, late-season snowdrifts.

Short-term streamflow forecasting techniques will be further refined, using melt data from several types of snowmelt collectors, snow courses, and energy balance measurements.

Long-term snowmelt streamflow forecasts will be further refined to include antecedent watershed precipitation conditions.

Snowmelt data will be collected for formulating a flood forecast model applicable to shallow snow--frozen ground--brush covered watersheds.

REPORTS AND PUBLICATIONS

Burgess, M. D. 1974
A digital telemetry system. August. (Station Report.)

Burgess, M. D., and L. M. Cox
A bipolar analog integrator for use with net radiometer. (Being reviewed for publication in Agricultural Meteorology.)

Burgess, M. D., and L. M. Cox 1974
A digital data acquisition system. June (Station Report.)

Cox, L. M., W. J. Rawls, and J. F. Zuzel 1974
Snow: Nature's Reservoir. (To be published in Proc. Tenth Amer. Water Resources Conf., Nov. 18-22.)

Johnson, C. W., L. M. Cox, W. J. Rawls, G. R. Stephenson, and J. F. Zuzel 1974
Instrumentation for hydrologic research on the Reynolds Creek Experimental Watershed. Accepted for publication in Proc. IWRA Internatl. Exposition and Seminar on water resources instrumentation, June 25.)

Robertson, D. C., J. F. Zuzel, and L. M. Cox 1974
Water Supply Outlook for Reynolds Creek Watershed as of March 14. (Station Report.)

Zuzel, J. F., and L. M. Cox 1974
Relative importance of meteorological variables in snowmelt. Accepted for publication in Water Resources Research, October 10.

Zuzel, J. F., D. C. Robertson, and W. J. Rawls 1974
Optimizing long-term streamflow forecasts. Accepted for publication in Jour. of Soil and Water Cons., October.

Zuzel, J. F., and W. T. Ondrechen 1975
A comparison of water supply forecast techniques for the Boise River. (Abstract accepted for presentation at ASCE Watershed Management Symp., Aug. 13-15, Logan, UT.)

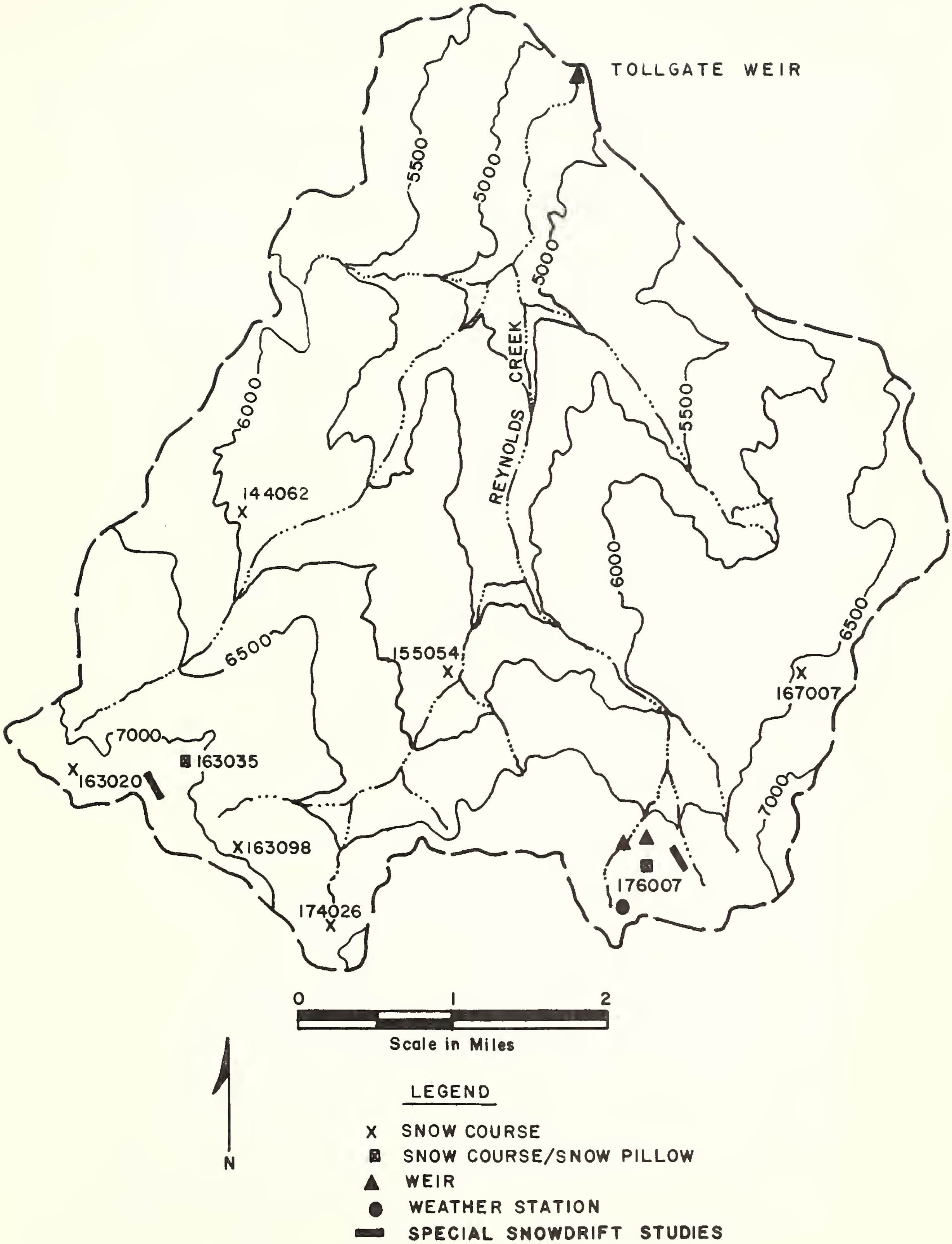

Figure 1. Tollgate Drainage

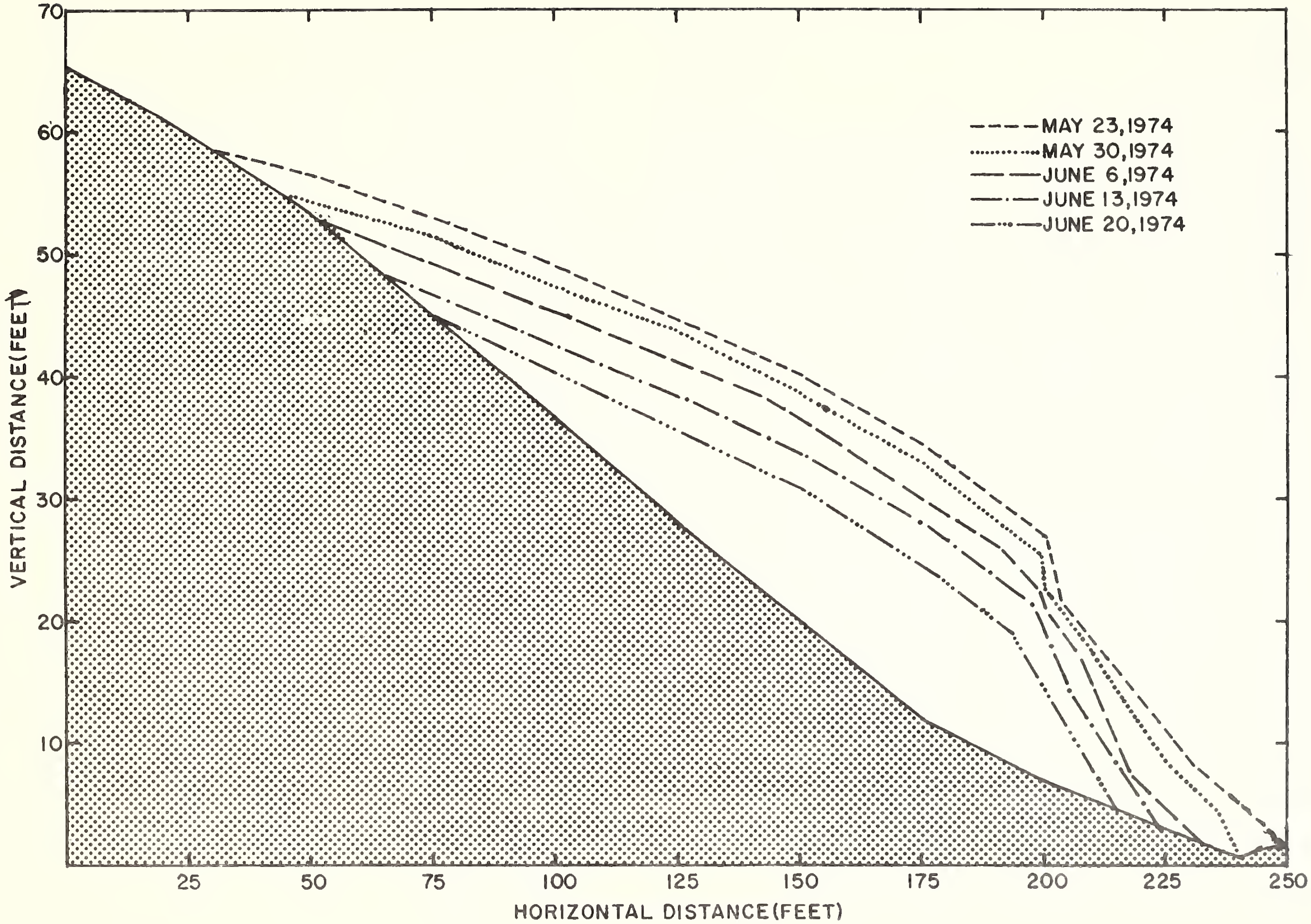

Figure 2. Snowdrift Surface Measurements for Five Successive Melt Periods

VEGETATION AND SOIL MOISTURE

Title: Evaluation of cover production, herbage yield, and soil conditions for different levels of vegetation management

Personnel Involved:

G. A. Schumaker, Soil Scientist	Plan, design, and coordinate research activities and prepare reports.
C. L. Hanson, Agr. Engr.	Perform computer analysis relative to soil moisture data and assist in analyzing field data.
D. L. Coon, Hydrol. Tech.	Responsible for various aspects of data collection and field observations, including soil moisture measurement and calibration; compile and process data.

Date of Initiation: May 1971

Expected Termination Date: Continuing

INTRODUCTION

Quantitative data on herbage yield from rangelands under different levels of management are needed to guide land managers in coordinated multiple use of the range. These needs require more discerning information on how vegetation and soils respond to imposed treatments, including controlled grazing. Information is also needed with regard to methods of increasing cover and to the rate of recovery of native range following intensive practices.

Objectives:

1. To determine the effects of grazing management and treatments on yield of herbage, cover production, soil moisture regime, and soil surface conditions at selected sites.

2. To study changes in plant density and plant composition as a result of grazing management and treatments.

PROGRESS

I. Vegetation

Data consisting of vegetation yield, cover comparison and basal area measurements of grasses were taken from all nine of the study sites at Reynolds Creek Experimental Watershed during the 1974 season. Descriptive information for each of the study sites is given in Table 1. Relative location of the study sites on the watershed are shown in Figure 1.

A. Herbage Yields: Winter precipitation on the Reynolds Creek Experimental Watershed was above normal; however, spring and early summer precipitation was almost nil. Warm temperatures in June hastened maturity of most grasses and forbs where clippings were being taken. Yields were lower than from previous years. Although the grasses matured rapidly, technicians were able to complete harvest at each of the sites before seed drop occurred. The double sampling technique was used in 1974 for measuring herbage yield as in previous years. Estimates of 20 samples were made on each treatment and, in addition, three samples were clipped and estimated. This technique has helped to reduce sample variability. As in previous years, the grazed treatments were subject to animal use except that sample points for 1974 were caged early in the season in order to determine total herbage produced.

1. Yields--Sparse Vegetation Sites: Yields from the sparse vegetation sites are shown in Table 2. More plant material was produced at sites being grazed, except for the flats site, than within the exclosure. At the Lower Sheep Creek and Reynolds Mountain (West) sites, yields under the grazed treatment were significantly greater at the 95 percent and 99 percent level, respectively.

The means of the two treatments over the five sites were significantly different at the 95 percent level. The effect of the exclosure treatment at the sparse vegetation sites covers a 5-year period. The areas were fenced in 1970. While the difference of 75 lbs. per acre between the means of the two treatments is relatively small, it indicates a trend and warrants continued study. Except for the Nettleton site, grazing pressure has not been heavy. The cattle movement that does occur during grazing may be sufficient to aid in the establishment of grasses following seed drop.

TABLE 1.--Tabulation of site information

SITE	ELEVATION (feet)	SLOPE 2/ (percent)	ASPECT OF SLOPE	PRECIPITATION 2/ (inches)	SOIL SERIES 2/	VEGETATIVE 2/ COVER (percent)	SCS HYDROLOGIC CLASSIFICATION
SPARSE VEGETATION SITES							
Flats	4000	5	North	9	Nannyton loam	<25	B
Nancy's Gulch	4600	8	Northeast	13	Glasgow loam	<25	C
Lower Sheep Creek	5400	16	Northwest	16	Searla gravelly loam	<25	B
Upper Sheep Creek	6100	25	Southwest	22 3/	Gabica cobbly gravelly loam	<25	D
Reynolds Mountain West	6850	5	Southwest	32 3/	Bullrey gravelly loam	<25	B
DENSE VEGETATION SITES							
Nettleton's 1/	5000	25	West	21	Reywat-Bakeoven rocky very stony loam	>50	D
Reynolds Mountain East	6800	6	Northwest	32 4/	Bullrey gravelly loam	>50	B
Upper Sheep Creek	6100	33	Northeast	22 4/	Harmehl and Demast loam	>50	C
Whiskey Hill	5550	15	East	17	Takeuchi rocky coarse sandy loam	>50	B

1/ Good grass cover site on soil developed from basalt.

2/ Based on 1961 survey.

3/ Snow removed by wind.

4/ Snow deposition zone.

The Nettleton grazed treatment was subjected to intense grazing from May 29 through June 11. The grazed area consists of 6.33 acres and was used by 12 head of cattle for a period of two weeks.

TABLE 2.--1974 yields from sparse vegetation sites under grazed and exclosure treatments

Study Site	Treatments	
	Exclosure 3/	Grazed
	lb/ac	lb/ac
Flats	628	533
Lower Sheep 1/	579	738
Nettleton	699	743
Upper Sheep Creek (Sparse)	333	370
Reynolds Mountain - West 2/	559	793
Mean 1/	560	635

1/ Differences between mean yield on exclosure and grazed treatments is significant at the 5.0% level.

2/ Differences between mean yield on exclosure and grazed treatments is significant at the 1.0% level.

3/ Not grazed four years prior to 1974.

2. Yields--Brush Treatment Studies: Yield data for 1974 has been analyzed with previous years' data and are discussed under the following headings beginning with the site at the lowest elevation. Data from the year the study was initiated at a particular site has not been included in the analysis.

   a. Nancy Gulch yields are for the period 1972 through 1974; non sagebrush yields are shown in Figure 2. Yields from both the mechanical and 2,4-D sprayed treatments were significantly greater than yields from either the untreated or grazed plots. Total herbage yields were not significantly different, Figure 3.

b. Whiskey Hill non sage yield averages for 1973 and 1974 were not significantly different, Figure 4, and total herbage yields were not significantly different, Figure 5.

c. Upper Sheep Creek yield averages for the years from 1971 through 1974 show that mechanical removal of brush produced significantly greater yields of non sage plant material than either no brush treatment or the grazed treatment, Figure 6. Good yield of grasses and forbs were produced where there was chemical control of sagebrush and the average was significantly different from the grazed treatment, Figure 6. Total herbage yields were not significantly different, Figure 7.

d. At Reynolds Mountain (East) both the mechanical treatment and 2,4-D spray treatments produced significantly greater non sage plant material than either the untreated or grazed plots, Figure 8. Total herbage yields of the no brush control and grazed plots were significantly different at the 95 percent level from either the mechanical or sprayed treatments, Figure 9.

B. Vegetative Cover: Cover Class, e.g., vegetation, litter, rock, or bare ground was noted at two different stages in 1974. Transects were taken at the nine study sites just prior to clipping the plots for yield when vegetative growth was at its maximum, Table 3. Additional late season measurements were taken at some of the sites in September and represent the cover make-up during dormancy, Table 4. Several comments with regard to these data seem appropriate although the data has not been subjected to statistical analysis. For the transects taken just prior to clipping, the presence of dead sagebrush on the sprayed plots is reflected in a higher percentage of litter. The grazed treatments have a higher percentage of bare ground except at the Reynolds Mountain (east) site, Table 3. In general, a greater amount of bare ground was exposed where an area is subjected to animal use. In many cases the differences are small. At the Upper Sheep Creek (sparse) site the amount of bare ground on the grazed treatment is considerably larger with 17 and 33 percent on the exclosure and grazed treatments, respectively.

TABLE 3.--1974 cover measurements taken at study sites prior to clipping

Location	Treatment	Vegetation %	Litter %	Rock %	Bare Ground %
Nancy	Mechanical	54.2	19.6	9.0	17.3
	Sprayed	50.2	25.7	7.3	16.9
	Untreated	45.0	21.1	13.3	20.6
	Grazed	41.3	14.3	16.3	28.1
Upper Sheep Creek	Mechanical	76.3	12.7	2.0	9.0
	Sprayed	66.9	26.9	0.3	6.0
	Untreated	78.5	17.7	0.3	3.4
	Grazed	63.8	24.9	.7	10.6
Reynolds Mountain	Mechanical	69.2	14.2	4.0	12.0
	Sprayed	47.4	39.6	3.8	9.2
	Untreated	70.2	18.6	4.2	7.0
	Grazed	65.6	22.8	3.6	8.0
Whiskey Hill	Sprayed	75.8	13.0	3.4	7.8
	Untreated	64.8	16.8	3.6	14.8
	Grazed	59.6	18.6	2.4	19.4
Flats	Exclosure[1/]	48.8	23.2	3.2	24.8
	Grazed	46.0	23.0	6.7	24.4
Nettleton	Exclosure[1/]	71.2	18.8	1.6	8.3
	Grazed	24.5	61.0	4.2	9.6
Lower Sheep Creek	Exclosure[1/]	46.1	12.6	22.5	18.7
	Grazed	42.4	13.2	27.6	17.0
Upper Sheep Creek (Sparse Site)	Exclosure[1/]	41.7	5.4	36.3	17.0
	Grazed	27.1	8.6	31.4	32.9
Reynolds Mountain (Sparse Site)	Exclosure[1/]	41.3	6.4	39.7	12.9
	Grazed	44.8	7.0	33.0	15.0

1/ Not grazed

Dormant season transects, Table 4, show a distinct increase in both percent bare ground and percent litter, when compared to transects taken prior to clipping.

TABLE 4.--1974 cover measurements taken at study sites late in the season during dormancy

Location	Treatment	Vegetation %	Litter %	Rock %	Bare Ground %
Nancy	Brush Removed	3.9	53.7	11.9	30.4
	Sprayed	8.0	50.5	12.2	29.0
	Untreated	14.3	42.0	11.5	32.1
	Grazed	15.1	32.5	10.8	41.4
Reynolds Mountain	Brush Removed	11.2	53.2	5.8	29.8
	Sprayed	7.4	55.0	1.6	36.0
	Untreated	48.4	26.4	1.6	23.6
	Grazed	51.2	34.8	3.0	11.0
Whiskey Hill	Sprayed	10.6	58.2	.4	30.8
	Untreated	30.4	40.2	0.0	29.4
	Grazed	38.0	30.8	.4	30.8
Flats	Exclosure[1/]	17.7	57.8	5.8	18.6
	Grazed	10.7	64.0	8.3	17.0
Reynolds Mountain-West (Sparse)	Exclosure[1/]	24.6	26.4	27.5	21.4
	Grazed	16.3	35.5	17.5	30.6

1/ Not grazed

C. Trend Plots: A series of photographs of the trend plots at each of the study sites were taken in 1974 to depict any changes in vegetative composition under the different treatments. Basal area measurements of the grasses were taken on the plots for the same purpose.

D. Plant Adaptability Nurseries: Sites were prepared and nurseries were seeded late in 1974 at three sites with different precipitation patterns. These sites were Flats, Nancy Gulch, and Reynolds Mountain. With the cooperation of the Intermountain Forest and Range Experiment Station, U. S. Forest Service, a wide selection of material was obtained for each of the nurseries. The list of species planted is given in Tables 5, 6, and 7 for the Flats, Nancy Gulch, and Reynolds Mountain sites, respectively. Plant emergences and survival information will be noted with regard to each selection. This information will aid in the selection of plant species used in range reseeding.

TABLE 5.--Species list for plantings in Flats Nursery

Scientific Name	Source	Scientific Name	Source
GRASSES		FORBS	
Agropyron cristatum x A. desertorum	Logan ARS	Achillea millefolium lanulosa	Reynolds Creek
A. cristatum fairway	Colorado, Commercial	Linum lewisii	Snow College farm
A. dasystachyum	Aberdeen PMC	Sanguisorba magnolii	Spain PI 319091
A. dasystachyum x A. caespitosum	Logan ARS	S. minor	NK Oregon Commercial
A. desertorum	Montana	S. muricatum	Spain PI 319094
A. desertorum	Montana (Nordan)	Tragopogon porrifolius	East of Boise
A. elmeri	Commercial		
A. intermedium	Wyoming (Oahe)	TREES AND SHRUBS	
A. intermedium	Commercial (Amur)		
A. intermedium	Commercial (Tegmar)	Artemisia tridentata vaseyana	Reynolds Creek
A. repens x A. cristatum	Logan ARS	Atriplex canescens	Jackson Springs, Utah
A. repens x A. desertorum	Logan ARS	A. "	Keans Canyon, Utah
A. riparium	Commercial (Sodar)	A. "	Panaca, Nevada
A. sibiricum	Idaho	A. "	Huntington, Utah
A. smithii	Montana, Commercial	A. "	Ephraim
A. spictatum	Montana, Commercial	A. "	Big Bear Lake, California
A. trachycaulum	Montana, Commercial	Atriplex canescens	Bridger, Montana
A. trichophorum	Colorado (Luna)	A. "	North Flagstaff
A. trichophorum	Idaho (Topar)	A. "	Reynolds Creek
Dactylis glomerata	Ephraim dryland form	A. confertilfolia	Reynolds Creek
D. glomerata	Yugoslavia PI 251112	Chrysothamnus nauseosus	Reynolds Creek
Elymus cinereus	East Boise, Dry Creek	C. vicidiflorus	Reynolds Creek
E. junceus	Mandan, N. Dakota (vinall)	Ephedra nevadensis	Pine Valley, Utah
E. junceus	Tetonia, Idaho	E. viridis	Manti, Utah
Oryzopsis hymenoides	Wyoming	Eurotia lanata	Hatch, Utah
Poa bulbosa	Pullman	E. lanata	Reynolds Creek
Secale montanum	Turkey PI 274912	Purshia glandulosa	Lincoln Co., Nebraska
S. montanum	Pullman SCS		

TABLE 6.—Species list of plantings in Nancy Nursery

Scientific Name	Source	Scientific Name	Source
GRASSES		FORBS	
Agropyron cristatum x A. desertorum	Logan ARS	Achillea millefolium lanulosa	Reynolds Creek
Agropyron dasystachyum	Aberdeen PMC	Balsamorhiza sagittata	Coeur d'Alene
A. dasystachyum x A. caespitosum	Logan ARS	Coronilla varia	Nebraska (Pennigift)
A. desertorum	Montana	C. "	Commercial (Emerald)
A. "	Montana (Nordan)	Hedysarum boreale utahensis	R. Stewart
A. elmeri	Commercial	Leptotaenia stipulacea	Iowa
A, intermedium	Wyoming (Oahe)	Linum lewisii	Snow College farm
A. "	Washington (Greenar)	Medicago falcatus	Pullman
A. "	Commercial (Amur)	M. sativa	Idaho (Rhizoma)
A. "	Commercial (Tegmar)	M. "	Idaho (Nomad)
A. repens x A. cristatum	Logan ARS	M. "	Idaho (Ladak)
A. repens x A. desertorum	Logan ARS	M. "	Canada (Rambler)
A. riparium	Commercial (Sodar)	M. "	Brookings, S. Dakota
A. sibiricum	Idaho	Medicago "	Northrup King
A. smithii	Montana, Commercial	Melilotus officinalis	Montana
A. spictatum	Montana, Commercial	Onobrychis viciaefolia	Czeckoslovakia (Viva)
A. trichophorum	Colorado (Luna)	O. "	Montana (Eski)
A. "	Idaho (Topar)	Sanguisorba magnolii	Spain PI 309091
Bromus inermis	Commercial	S. minor	NK Oregon Commercial
B. "	GBRS (Northern)	S. muricatum	Spain PI 319094
B. "	(Manchar) Commercial	Solidago gigantea	Reynolds Creek
Bromus marginatus	Pullman SCS (Bromar)	Trifolium fragiferum	California
B. tomentellus	SCS		
Calamagrostis epigeios	Commercial	TREES AND SHRUBS	
Dactylis glomerata	Commercial (Potomac)		
D. "	Ephraim dryland form	Amelanchier alnifolia	Bonneville Co., Idaho
D. "	Yugoslavia PI 251112	A. utahensis	Reynolds Creek
Elymus cinereus	East Boise, Dry Creek	Artemisia tridentata vaseyana	Reynolds Creek
E. junceus	Tetonia, Idaho	Cercocarpus montanus	Diamond Fork, Utah
Festuca ovina duriuscula	Idaho (Dorar)	Chrysothamnus nauseosus	Reynolds Creek
F. ovina sulcata	PI 229450	C. viscidiflorus lanceolatus	Reynolds Creek
Oryzopsis hymenoides	Wyoming	Cowania mexicana stansburiana	American Fork, Utah

TABLE 6.—Species list of plantings in Nancy Nursery (Cont'd)

Scientific Name	Source	Scientific Name	Source
GRASSES (Cont'd)		TREES AND SHRUBS (Cont'd)	
Phleum pratense	Missouri	Cowania mexicana stansburiana	Pioche, Nevada
Poa pratensis	Commercial	Ephedra nevadensis	Pine Valley, Utah
Secale montanum	Turkey PI 274912	E. viridis	Manti, Utah
S. "	Pullman SCS	Eriogonum umbellatum	Shaffer Butte
Stipa viridula	Montana, Commercial	Erotia lanata	Hatch, Utah
		Prunus emarginata	Reynolds Creek
		P. virginiana melanocarpa	Reynolds Creek
		Purshia tridentata	Moffet Co., Colorado
		P. "	Freemont Co., Utah
		P. "	Boise
		P. "	Eureka, Utah
		P. "	Mono Lake, California
		P. "	Washoe Co., Nevada
		Sambucus cerulea	Reynolds Creek

TABLE 7.--Species list of plantings in Reynolds Mountain Nursery

Scientific Name	Source	Scientific Name	Source
GRASSES		FORBS	
Agropyron cristatum x A. desertorum	Logan ARS	Achillea millefolium lanulosa	Reynolds Creek
A. cristatum Fairway	Colorado, Commercial	Balsamorhiza macrophylla	Cache Co., Utah
A. dasystachyum	Aberdeen PMC	B. sagittata	Coeur D'Alene
A. dasystachyum x A. caespitosum	Logan ARS	Coronilla varia	Nebraska (Pennigift)
A. desertorum	Montana	C. "	Commercial (Emerald)
A. "	Montana (Nordan)	Ephedra nevadensis	Pine Valley, Utah
A. elmeri	Commercial	Eriogonum	Grimes Creek, Idaho
A. intermedium	Wyoming (Oahe)	Eriogonum umbellatum	Shaffer Butte
A. "	Washington (Greenar)	Hedysarum boreale utahensis	R. Stewart
A. "	Commercial (Amur)	Lesedeza stipulacea	Iowa
A. "	Commercial (Tegmar)	Linum lewisii	Snow College farm
A. junceum	France PI 276566	Ligusticum porteri	Ephraim Canyon
A. repens x A. desertorum	Logan ARS	Lotus corniculatus	Vermont (Broadleaf)
A. riparium	Commercial (Sodar)	L. "	California (narrowleaf)
A. sibiricum	Idaho	L. "	Canada (Empire)
A. smithii	Montana, Commercial	L. "	Iowa
A. spicatum	Montana (")	Lupinus sericeus	Cedar Mountain, Utah
A. trachycaulum	Montana (")	L. species	South of Twin Falls
Agropyron trichophorum	Colorado (Luna)	Medicago falcatus	Pullman
A. trichophorum	Idaho (Topar)	Melilotus officinalis	Montana
Alopecurus pratensis	Commercial	Medicago sativa	
Bromus biebersteinii	Aberdeen SCS	M. "	
Bromus carinatus	Leadville, Colorado	M. "	
B. inermis	U.S.S.R. PI 315374	M. "	
B. "	U.S.S.R. PI 315378	M. "	
B. "	GBRS (Northern)	M. "	
B. "	Commercial (Manchar)	Onobrychis viciaefolia	Czechoslovakia (Viva)
B. "	Commercial (Lincoln)	O. "	Montana (Eski)
B. marginatus	Pullman SCS (Bromar)	Osmorhiza occidentalis	Anderson Dam
B. tomentellus	SCS	O. "	Middle Fork Payette
Calamagrostis epigeios	Commercial	Penstemon palmeri	

TABLE 7.--Species list of plantings in Reynolds Mountain Nursery (Cont'd)

Scientific Name	Source	Scientific Name	Source
GRASSES (Cont'd)		FORBS (Cont'd)	
Dactylis glomerata	Yugoslavia PI 251112	Sanguisorba magnolii	Spain PI 319091
D. "	Ephraim dryland form	S. minor	NK Oregon, Commercial
D. "	Australia PI 209888	Solidago gigantea	Reynolds Creek
Elymus cinereus	East Boise, Dry Creek	Trifolium fragiferum	California
Festuca arundinacea	Commercial (Fawn)	Vicia villosa	Major's Flat, Utah
F. ovina duriuscula	Idaho (Doran)		
F. "	PI 229450	TREES AND SHRUBS	
Phleum pratense	Missouri		
Poa ampla	Washington, Commercial	Acer glabrum douglasii	Reynolds Creek
P. compressa	Northrup King	Amelanchier alnifolia	Woodland, Utah
P. pratensis	Commercial	A. "	Bonneville Co., Idaho
Secale montanum	Pullman SCS	A. "	Reynolds Creek
Stipa viridula	Montana, Commercial	A. utahensis	Henryville, Utah
		Artemisia tridentata	Reynolds Creek
		Cercocarpus betuloides	Red Bluff, California
		C. "	Reynolds Creek
		C. ledifolius	Reynolds Creek
		C. ledifolius intricatus	Ephraim Canyon
		Cercocarpus montanus	Ephraim
		C. "	Diamond Fork, Utah
		C. "	Reynolds Creek
		C. "	Pinto, Utah
		Ceanothus velutinous	Reynolds Creek
		Cowania mexicana stansburiana	American Fork, Utah
		C. " "	Pioche, Nevada
		Holodiscus dumosus	Reynolds Creek
		Juniperus occidentalis	Reynolds Creek
		Prunus emarginata	Reynolds Creek
		P. virginiana melanocarpus	Reynolds Creek
		Purshia glandulosa	Lincoln Co., Nebraska
		P. tridentata	Moffet Co., Colorado
		P. "	Fremont Co., Idaho

TABLE 7.—Species list of plantings in Reynolds Mountain Nursery (Cont'd)

Scientific Name	Source	Scientific Name	Source
		TREES AND SHRUBS (Cont'd)	
		Purshia tridentata	Boise
		P. "	Eureka, Utah
		P. "	Mono Lake, California
		Rosa woodsii	Reynolds Creek
		Sambucus cerulea	Reynolds Creek
		Symphoricarpos oreophilus	Bear Lake, Utah
		S. "	Reynolds Creek

II. Soils

A. Erosion Condition: Observations for soil surface factor determinations were taken on the different treatments at each of the study sites in 1974, Table 8. The Upper Sheep Creek and Lower Sheep Creek sparse vegetation sites were given the erosion condition class of slight, as in previous years. At the Nancy Site the mechanical and grazed treatments were given the classification of slight although both were bordering between stable and slight.

TABLE 8.--Summary of soil surface factor determinations at the vegetation study sites in 1974

	Mechanical	Sprayed	Untreated	Grazed
	SSF	SSF	SSF	SSF
Flats	---	---	17	20
Lower Sheep	---	---	25	21
Nettleton	---	---	13	17
Upper Sheep	---	---	34	37
Reynolds Mountain (West)	---	---	20	18
Nancy	21	19	22	27
Whiskey Hill	---	3	4	15
Upper Sheep (Dense)	0	0	3	8
Reynolds Mountain (East)	1	0	0	7

Stable = 0-20
Slight = 21-40

B. Soil Moisture: Soil water measurements were taken at the four brush treatment studies during the 1974 growing season. Measurements began early in the season when the soil profile was at or near its maximum and continued until roots had extracted the available water from the measured depth of the soil profile. Soil water content for the Nancy Gulch and Whiskey Hill sites are shown in Figures 10 and 11, respectively. These data indicate that brush treatment did not consistently alter the moisture use pattern at either of these sites. At Upper Sheep Creek water use reached its maximum during the period of June 10 to June 25, Figure 12.

Where the brush had not been treated water use was slightly less than where either the mechanical or chemical treatments had been used. At Reynolds Mountain, Figure 13, moisture loss was at a high rate from the period of June 10 through August 20. The daily rate of loss was in excess of .20 inches per day for this period. The pattern of loss was not greatly different for any of the three types of brush treatment under study. Although soil water data was taken at the Upper Sheep Creek and Reynolds Mountain sites throughout the growing season the September data has not been summarized for the report.

SIGNIFICANT FINDINGS

The mean herbage yields calculated from the five sparse vegetation grazed sites and the five exclosure sites were significantly different.

Analysis of yield data from the brush treatment studies on the watershed showed significant differences between either brush control by mechanical or chemical means and no treatment at three of the four sites studied. The Whiskey Hill site had been operated for fewer years and the comparisons were not significantly different.

Cover measurements taken at the end of the season showed increases in percent bare ground and litter over measurements taken when plant growth was near its maximum.

WORK PLAN FOR FY 76

Measurement of changes in species composition, cover, herbage, yield, and soil surface condition will be continued.

Water use under different types of brush control will be continued.

Dormant season cover measurement at study sites will be continued.

Collect data on emergence and persistence of various species of grasses, forbs, and shrubs in adaptability studies at three locations.

Establish a land treatment, grass establishment study at the Flats.

Develop forage productivity forecast equations for elevation sites.

REPORTS AND PUBLICATIONS

None

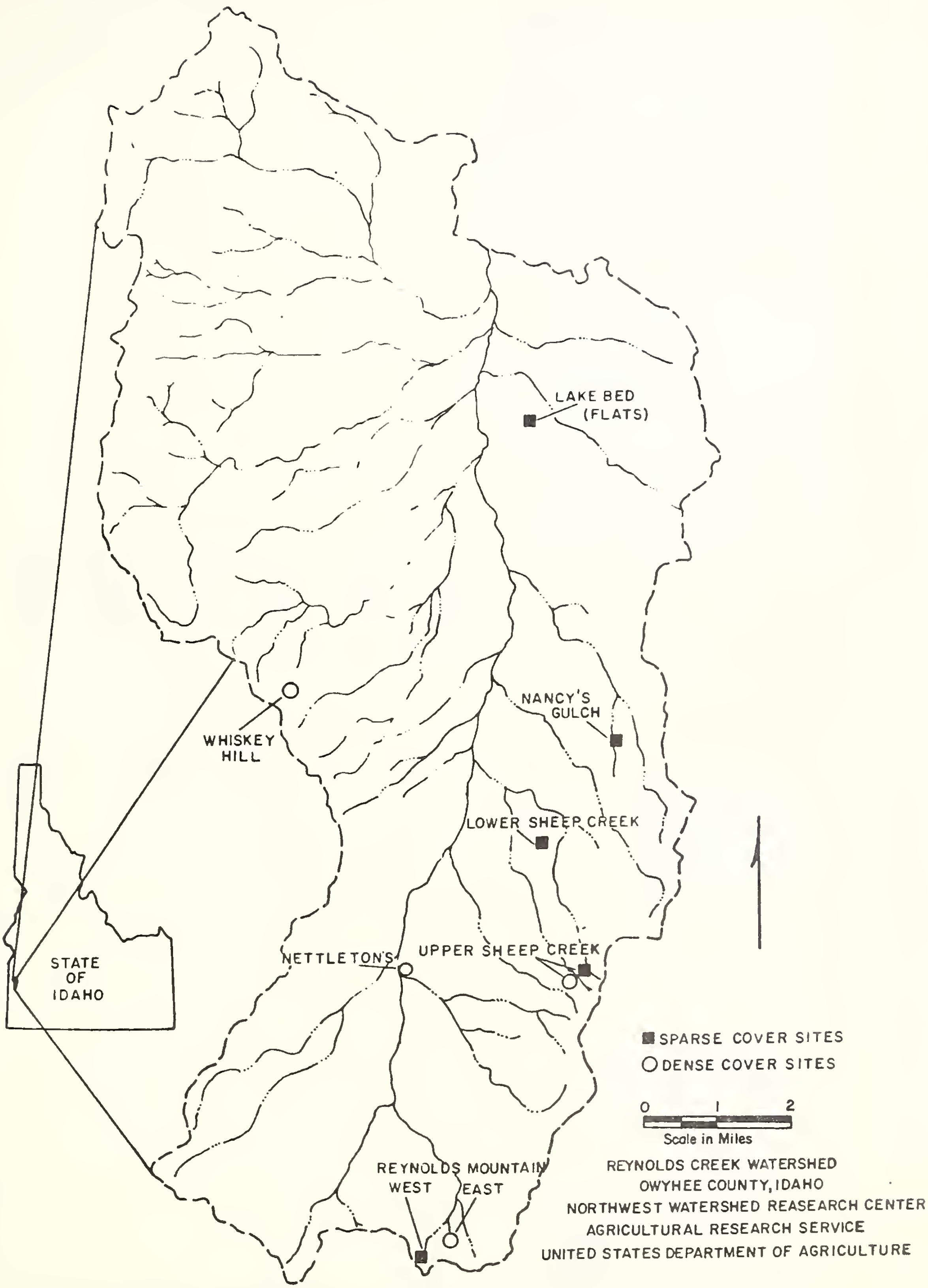

Figure 1. Location of experimental sites.

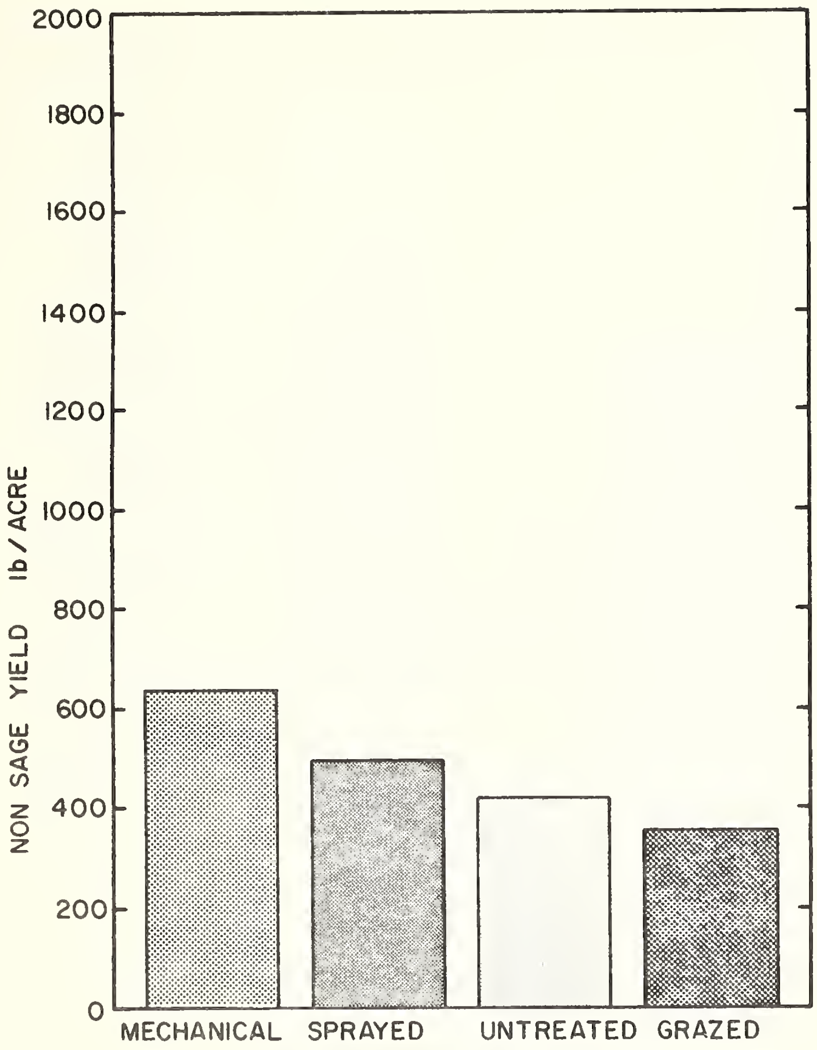

Figure 2. Average yield of non sage plant material at Nancy Gulch from 1972-1974

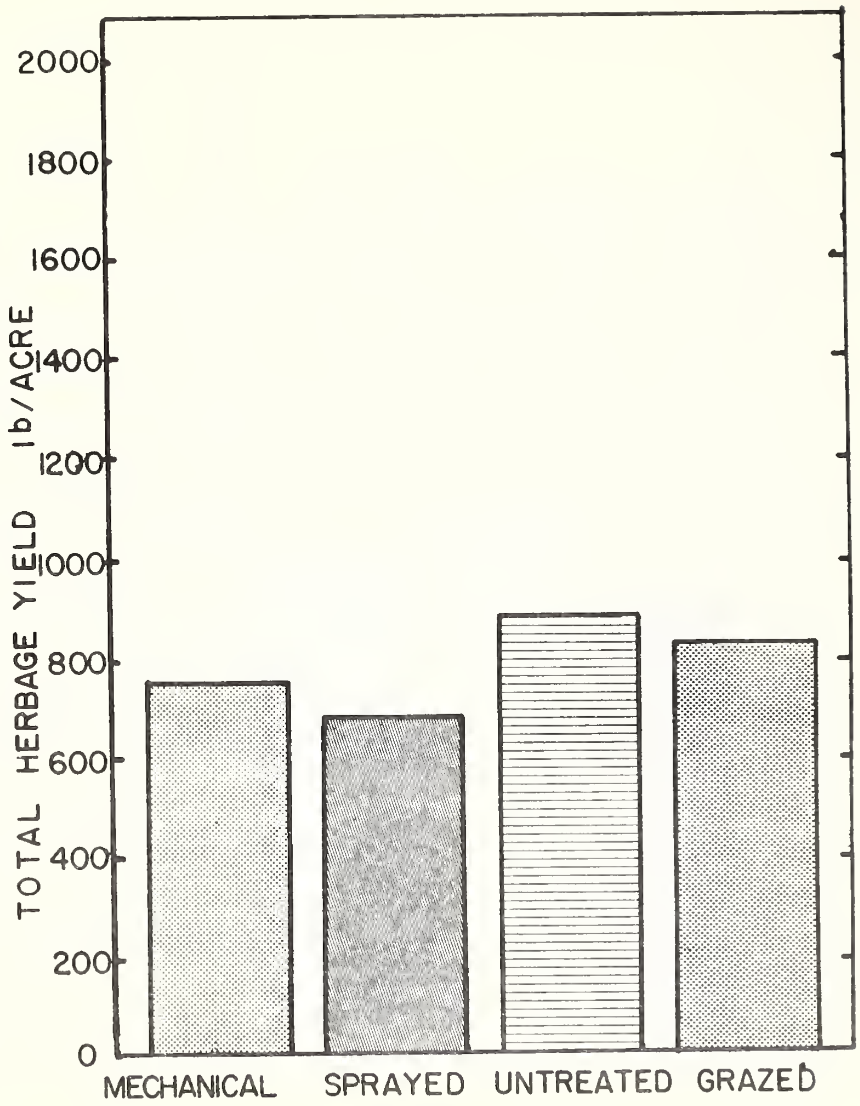

Figure 3. Total herbage yield from the Nancy Gulch brush treatment, 1972-1974 averages

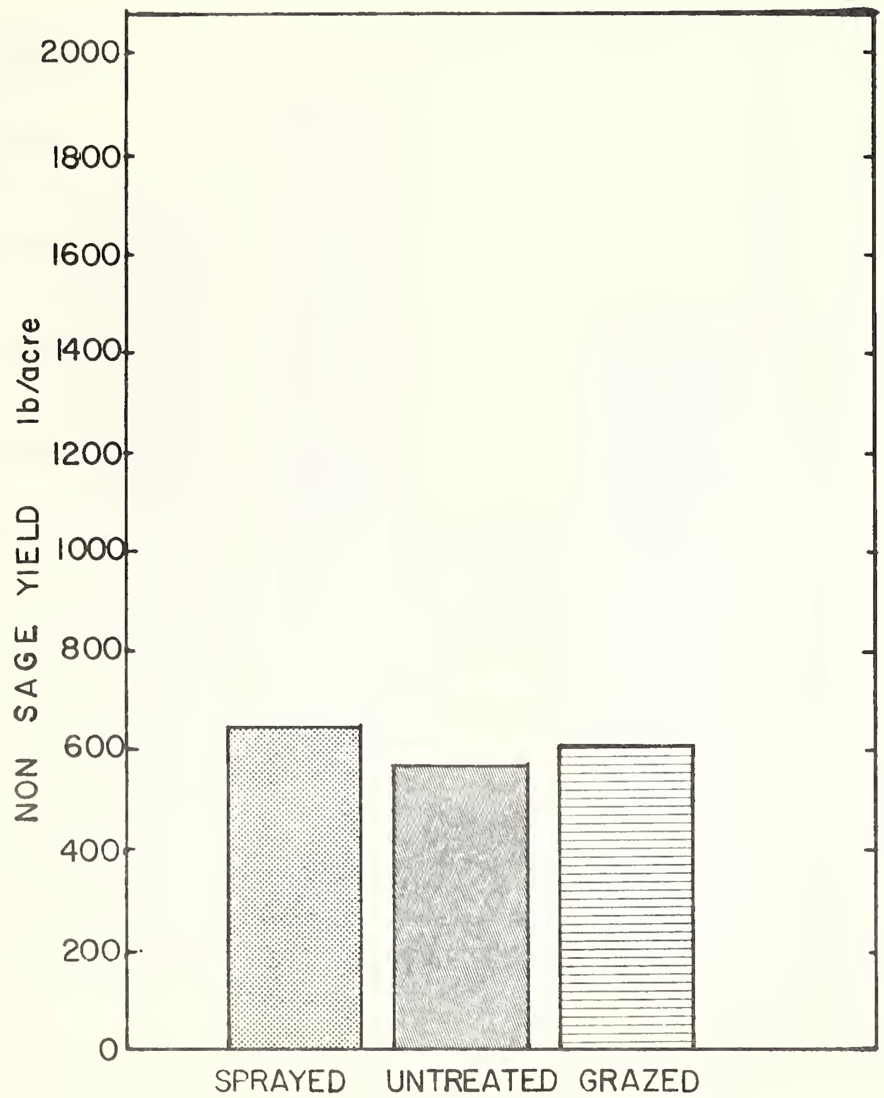

Figure 4. Average yield of non sage plant material at Whiskey Hill for 1973 and 1974

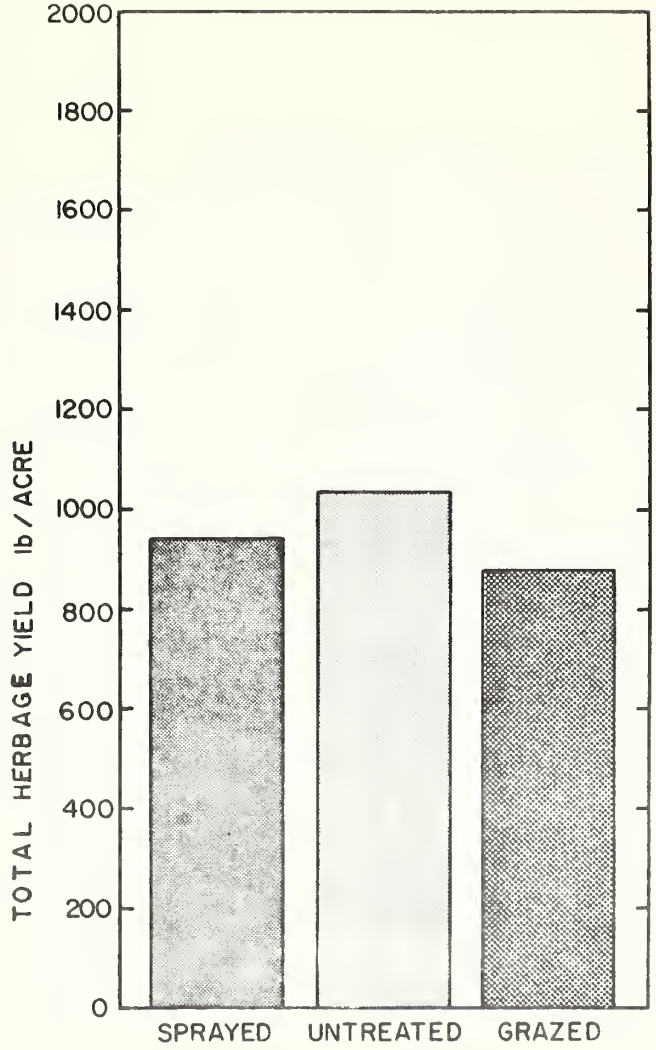

Figure 5. Total herbage yield at the Whiskey Hill brush study, 1973-1974 average

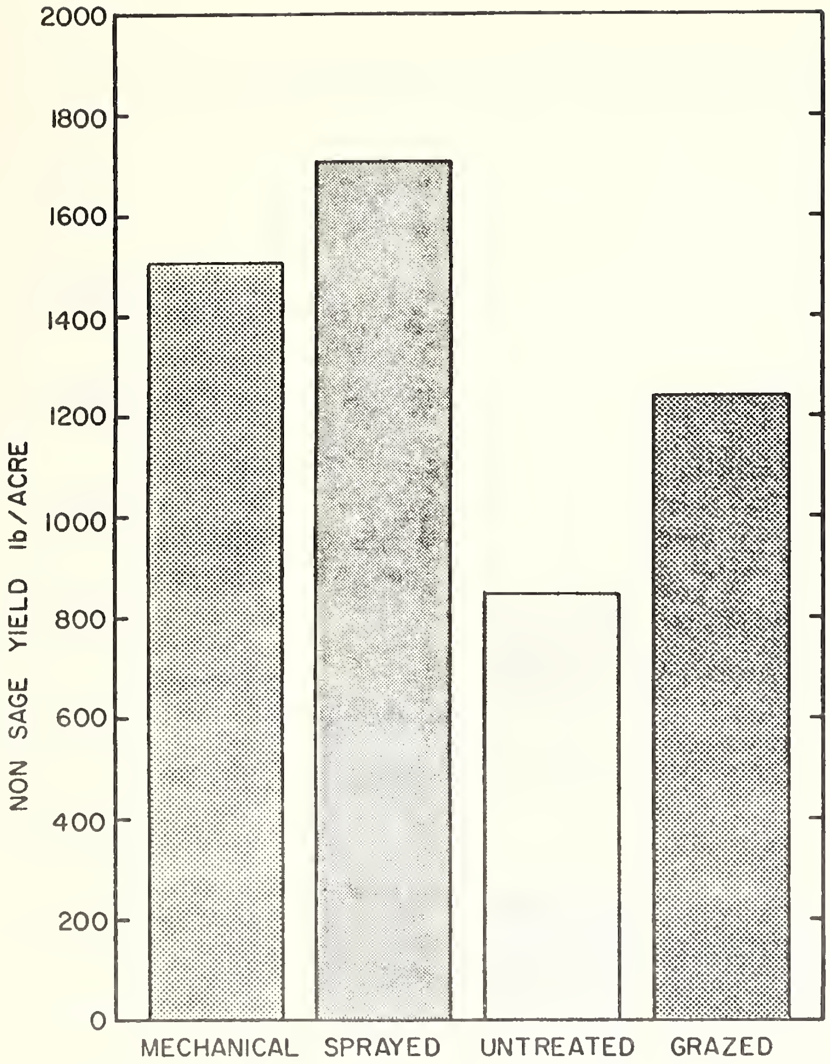

Figure 6. Average yield of non sage plant material at Upper Sheep Creek from 1971-1974

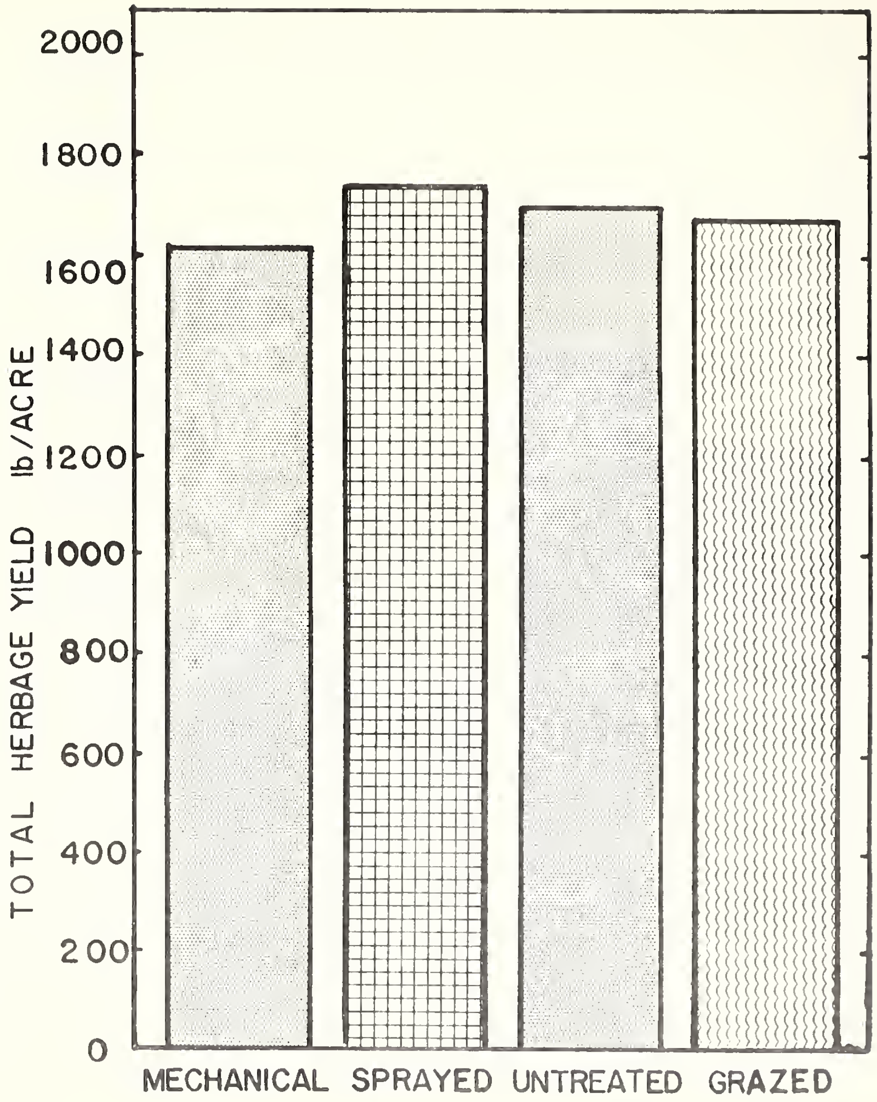

Figure 7. Total herbage yield from the Upper Sheep Creek brush treatment study, 1971-1974 average

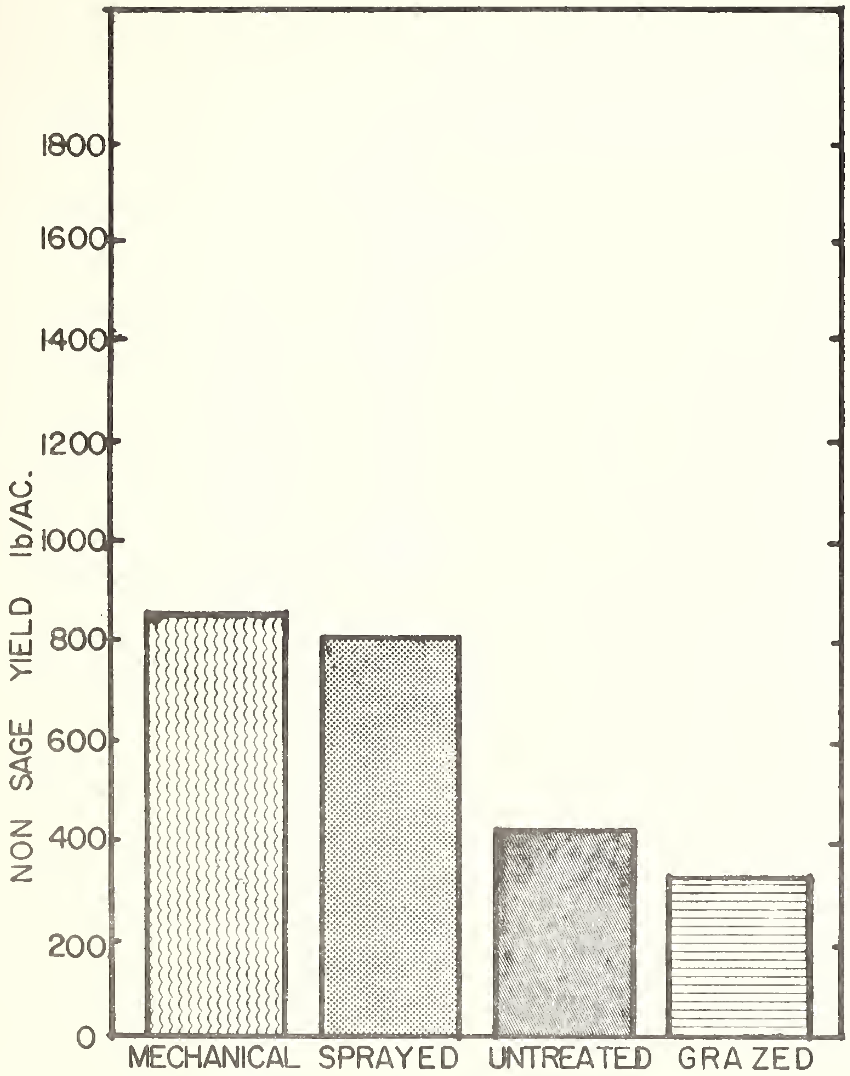

Figure 8. Average yield of non sage plant material at Reynolds Mountain from 1972-1974

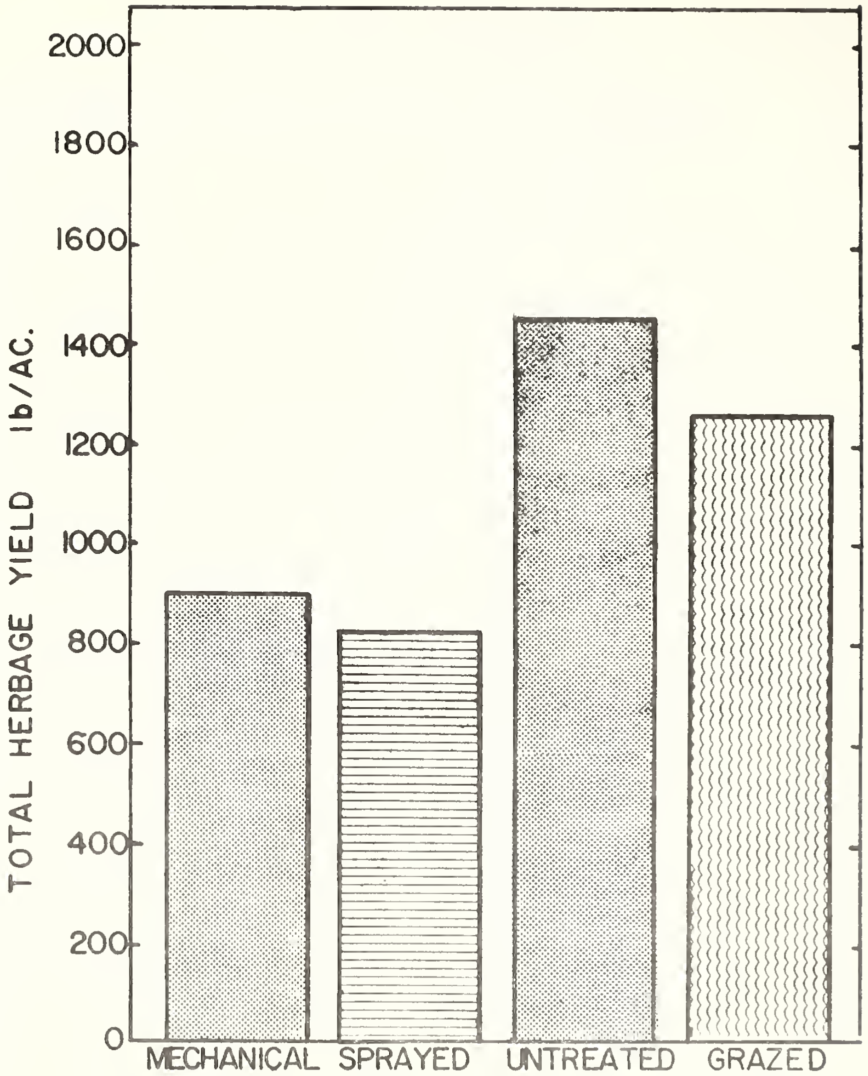

Figure 9. Total herbage yield from the Reynolds Mountain brush treatment study, 1972-1974 average

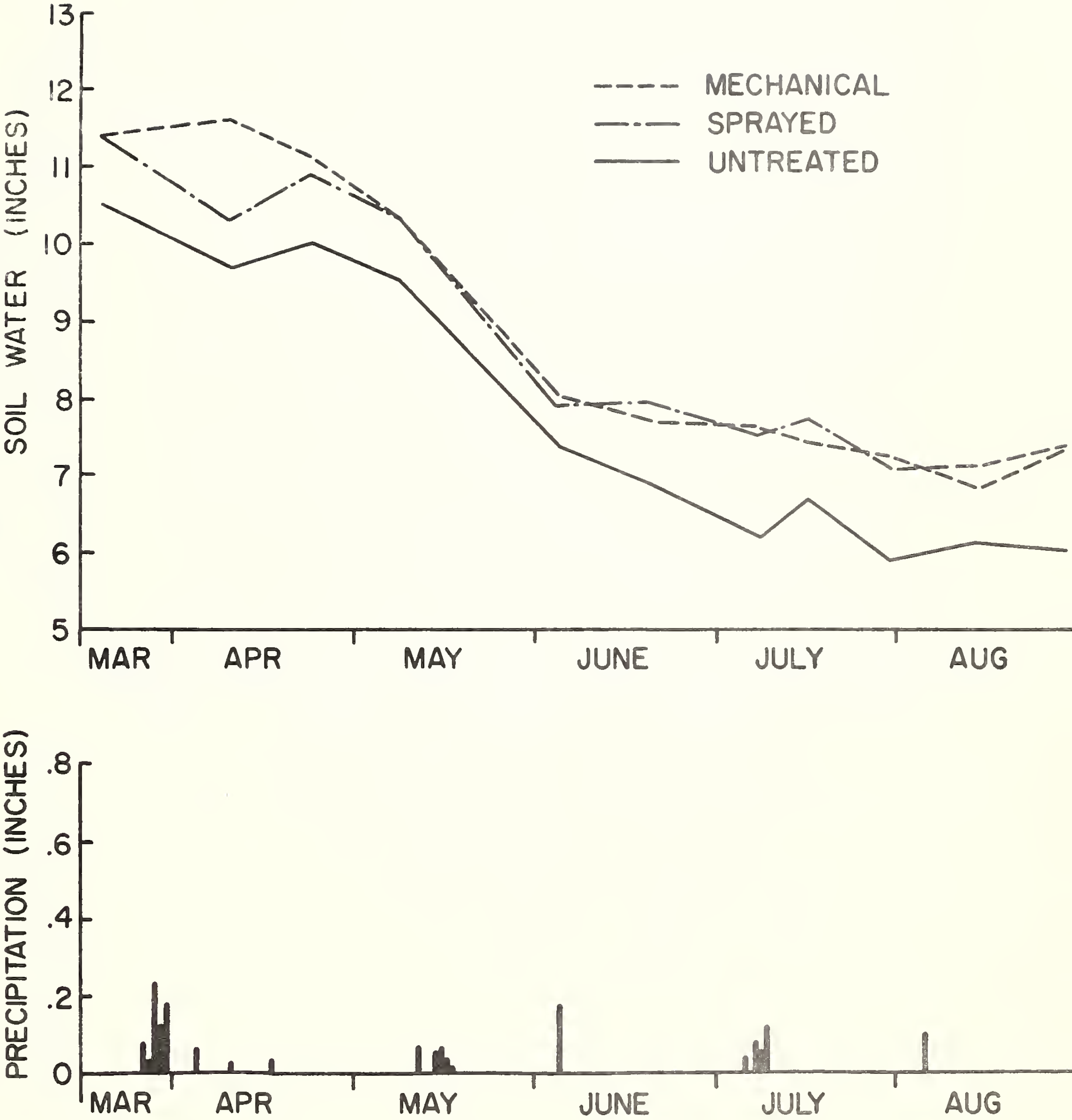

Figure 10. Soil water content for the 0 to 2.5 ft depth during the growing season for three different brush treatments at Nancy Gulch, 1974

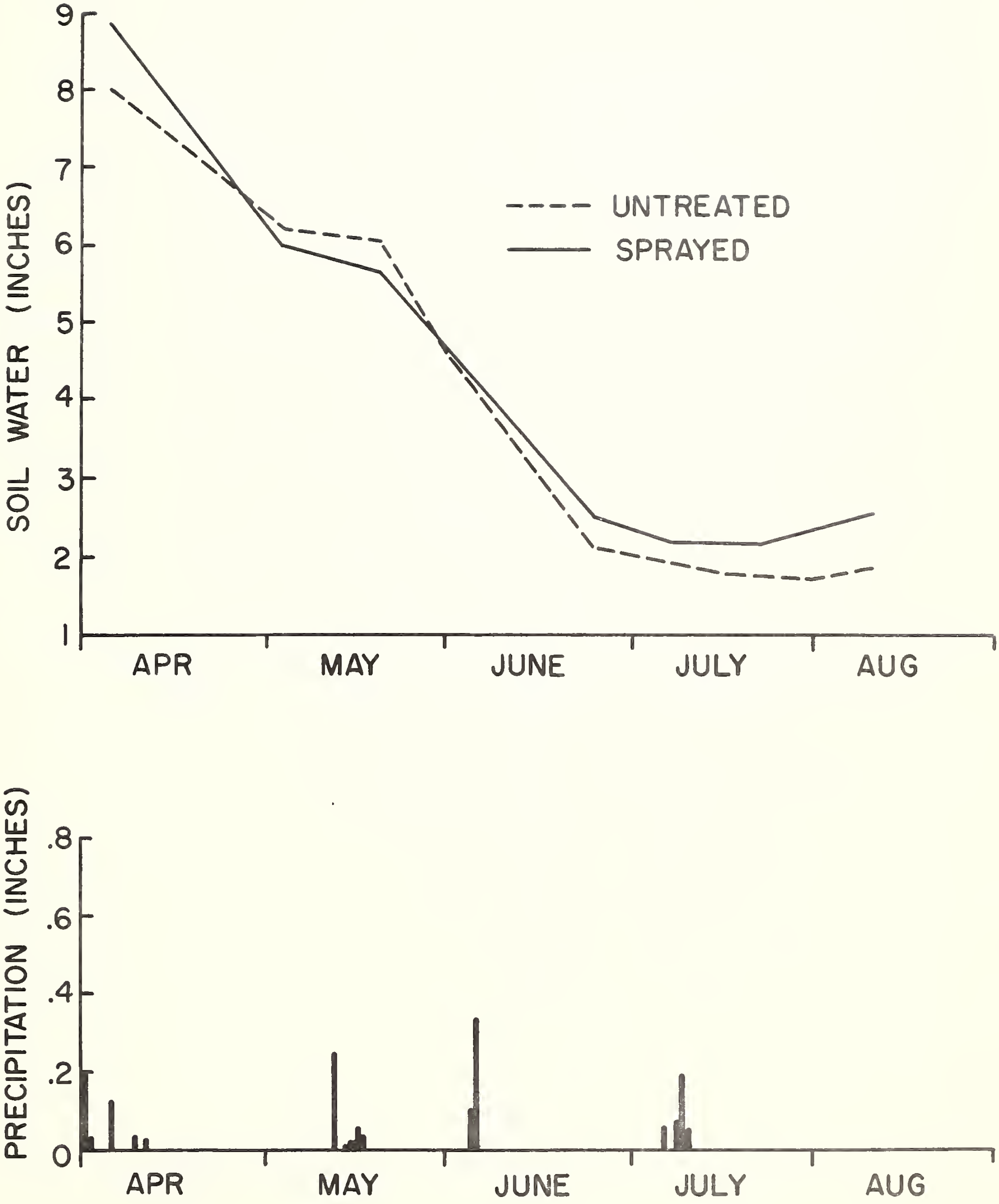

Figure 11. Soil water content for the 0 to 2.5 ft depth at Whiskey Hill brush treatment site, 1974

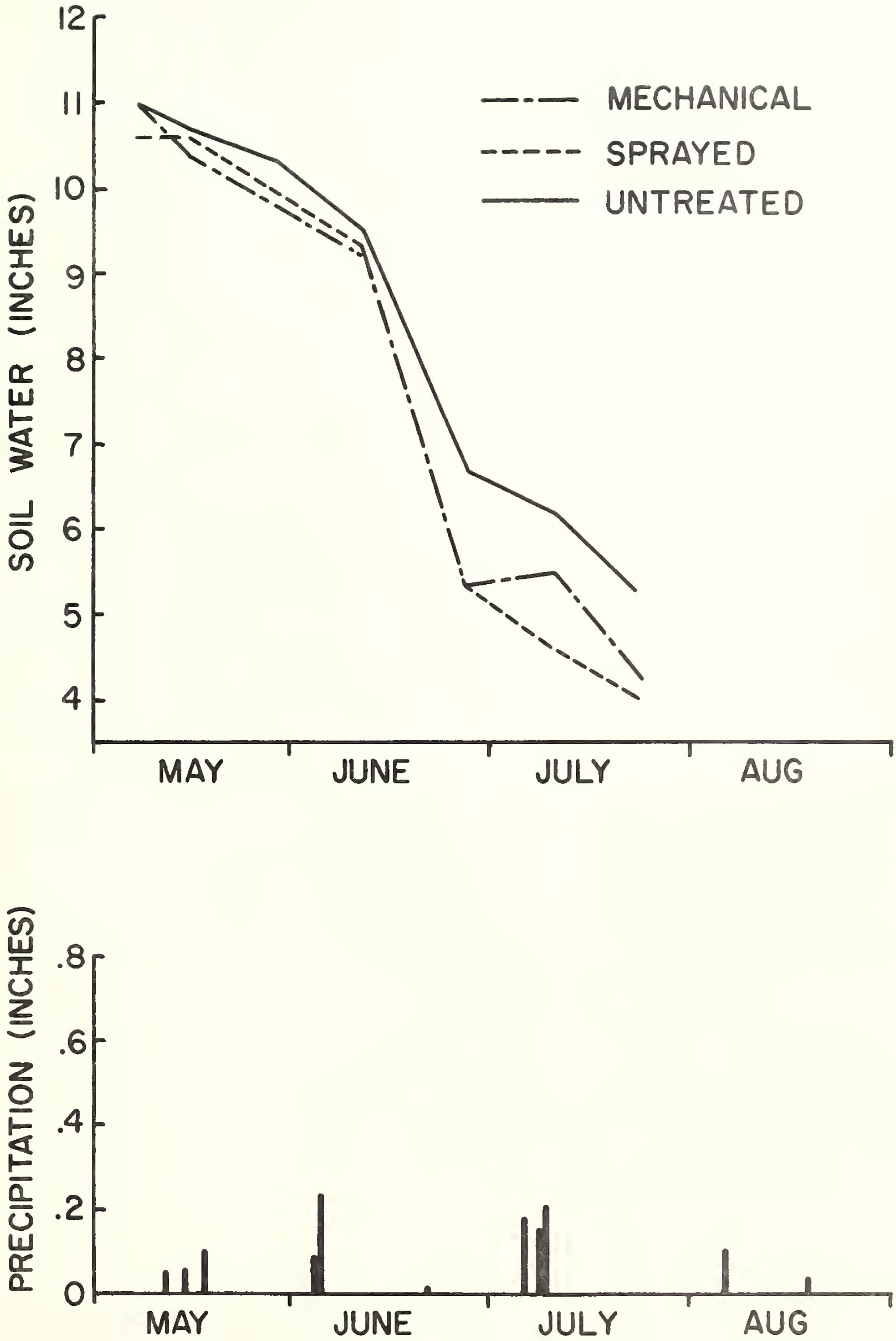

Figure 12. Soil water content for the 0 to 2.5 ft depth during the growing season for three different brush treatments at Upper Sheep Creek, 1974 (August and September data not yet processed.)

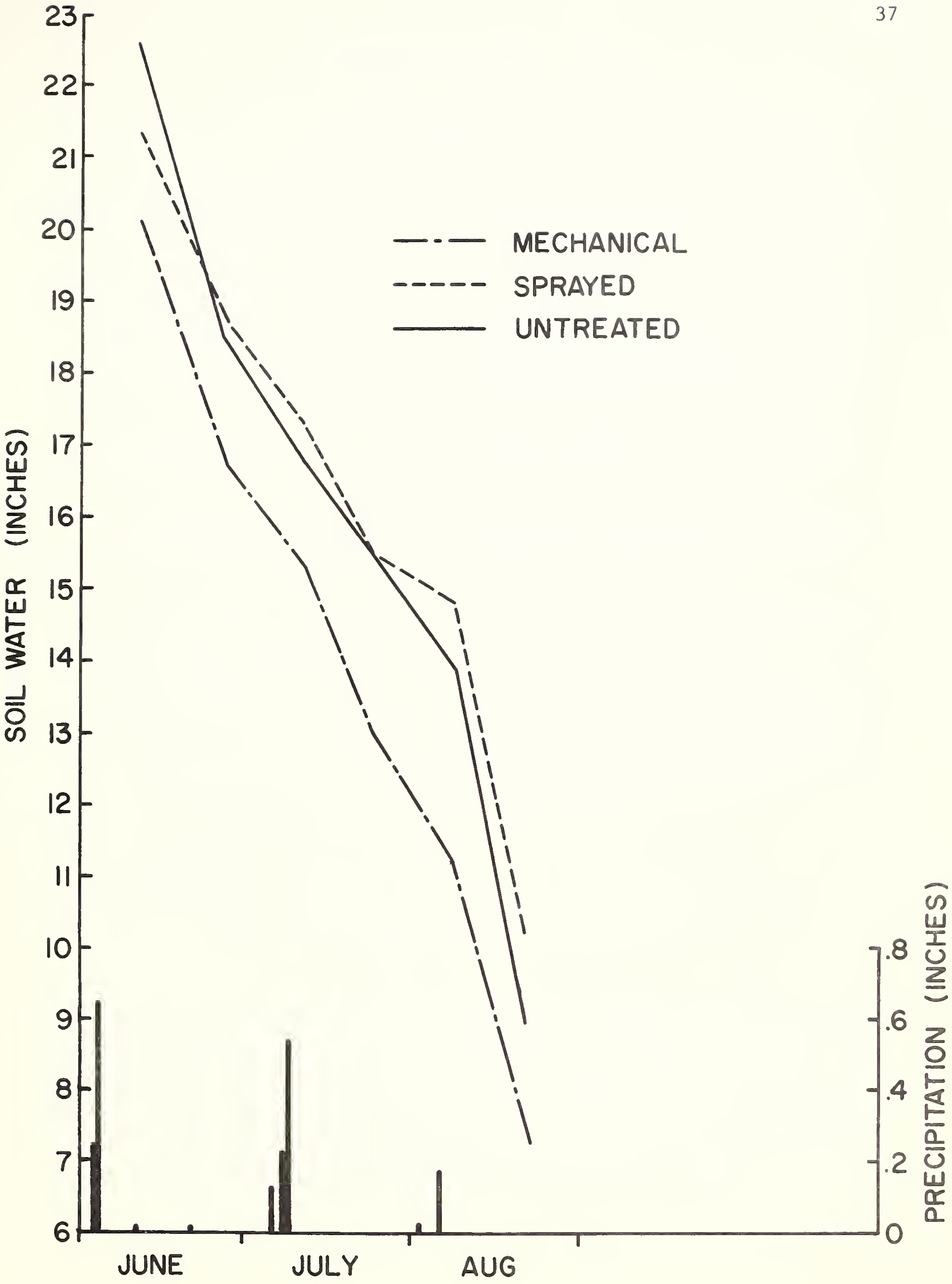

Figure 13. Soil water content for the 0 to 2.5 ft depth during the growing season for three different brush treatments at Reynolds Mountain, 1974 (September data not yet processed.)

TERMINATION REPORT

INFILTRATION

Title: Developing, testing, and evaluating an analytical infiltration model

Personnel Involved:

W. J. Rawls (Transferred December 1974 to Beltsville, Maryland)	Supervise field data collection; coordinate the research with the cooperators; perform any other analysis needed
G. A. Schumaker (ARS-Boise)	Collect necessary soils and vegetation data
W. R. Hamon (ARS-Coshocton, Ohio)	Coordinate the 5-year technical bulletin on infiltration work performed at Boise
R. W. Jeppson (Utah State University)	Develop and field test analytical infiltration models
R. H. Brooks (Oregon State University)	Assess soil properties in laboratory and in the field; help establish field procedures; help develop and field test analytical infiltration models

Date of Initiation: February 1971

Termination Date: December 1974

INTRODUCTION

Infiltration of water into soil profiles is probably the most critical hydrologic component in watershed management, overland flow prediction, sediment generation, natural and artificial ground-water recharge, and irrigation. More accurate information concerning the flow system resulting from infiltration is essential if agricultural lands are to be managed for optimum multiple use. The Northwest Watershed Research Center has been conducting an infiltration research program aimed at developing, testing, and evaluating analytical infiltration models.

Objectives:

1. To develop or adapt mathematical models in the form of partial differential equations to describe steady-state and transient one-dimensional and three-dimensional axisymmetric flow through partially saturated soils.

2. To use mathematical models to adjust for the lateral "spreading effect" of moisture movement from a circular rainfall simulator under various soil types and conditions.

3. To test and refine the mathematical models by comparing results with laboratory and field determinations of infiltration, and to establish the relative influence of the several interacting physical processes on infiltration.

4. To determine the saturation-pressure relationship (moisture characteristic) and saturated conductivity parameters by the use of parameter optimization in conjunction with the mathematical models and infiltration data.

5. To determine the potential quantity of water retainable by various soil-vegetation complexes independent of infiltration and different initial soil moisture levels.

The abstracts of all publications connected with this project are included in the Reports and Publication section. Additional copies of any publication can be obtained from the Northwest Watershed Research Center, P. O. Box 2700, Boise, Idaho 83701.

PROGRESS

A summary of the progress of this project is contained in the ARS-BLM Cooperative Studies Interim Reports 1 through 4.

SIGNIFICANT FINDINGS

1. A rainfall simulator with a combination of capillary needle sizes, air and water pressure, which is capable of duplicating the median drop sizes of natural rainfall up to intensities of 8 inches/hour, was developed. The control of drop sizes and intensities also makes it possible to produce a desired rainfall energy even though terminal velocities are not reached. A gamma probe and a tensiometer pressure transducer system were combined with the rainfall simulator such that saturation-pressure data could be obtained during rainfall. (Publications 10, 11, and 16.)

2. Mathematical models of transient, partially saturated, one-dimensional vertical and three-dimensional axisymmetric, flow through soils have been developed and verified by laboratory data obtained from a soil from the Reynolds Creek Experimental Watershed. A modified Burdine Theory provides a functional relationship for obtaining, from saturation-capillary pressure data, the change of relative hydraulic conductivity with capillary pressure. Reasonably good agreement is attained between observed conductivity-pressure data and the results predicted by the modified Burdine Theory. Solution results from the two mathematical models indicate that boundary effects on circular infiltrometers significantly alter the flow pattern, even reducing the saturation at the surface centerline appreciably over that which would exist for the same application rate over an infinite area. (Publications 2, 3, 4, and 6.)

3. Finite-difference solutions of steady-state, axisymmetric, moisture movement from horizontal source surfaces through homogeneous, partially saturated soils indicated that significant radial movement (spreading effect) of moisture occurs and is closely related to the hydraulic properties of the soils. Results also showed that low surface moisture content outside the area of application caused radial moisture movement into this region as evidenced by high infiltration at the edge of the source circle. (Publications 7, 9, 12, 13, 14, and 15.)

4. Procedures and field equipment for collecting infiltration data and pressure-saturation data in the field were perfected. Also, infiltration data from three rangeland sites were successfully collected. (Publications 1, 10, 11, and 12.)

5. A procedure for determining the hydraulic properties of soils in situ was developed. It was found that present equations representing the capillary pressure-saturation relationship during drainage are not applicable for imbibition. Also, a comparison of in situ capillary pressure-saturation data and laboratory capillary pressure-saturation data indicated a good correspondence at the surface or just below the surface; however, this was not true at lower depths. (Publications 5, 8, 12, and 15.)

WORK PLAN FOR FY 1976

None

REPORTS AND PUBLICATIONS

1. Computer Sciences Corporation, Richland, Wash. 1968. Theoretical and experimental aspects of watershed infiltration in terms of basic soil properties. A research and development planning survey by R. William Nelson and Roland W. Jeppson. To Utah Water Res. Laboratory, Utah State Univ., Logan, for Northwest Watershed Research Center, ARS-SWC-USDA, Boise, Idaho CSC 6810-1.

The purpose of this report is to analyze watershed infiltration from the standpoint of the known physical laws acting and provide possible mathematical models of the systems. Then, based upon the analysis survey, provide detailed recommendations for the specific studies needed in the theoretical, experimental, and field measurement areas to assure usable infiltration results. Specifically, the material presented here will include:

(1) Recommendations of the specific studies needed and a suggested order for conducting them.

(2) Mathematical formulations of the boundary value problems modeling the infiltration process.

(3) Consideration of the soil properties to be measured and suggest possibilities for field measurement, and

(4) Consideration of those areas of insufficient knowledge and experience which are the basis for Item 1 above.

2. PRWG-59-c-1 Jeppson, R. W. 1969
Numerical solution of the steady-state two-dimensional flow system resulting from infiltration on a watershed. Utah Water Res. Lab., Coll. of Engin., Utah State Univ., Logan.

ABSTRACT
The material contained in this report is divided into the following major categories: (1) a mathematical description of the physical problem of two-dimensional flow and the resulting inverse equations; (2) a description of the two-dimensional model of the watershed flow system; (3) a description of the solution method; and (4) presentation of a number of solutions obtained by specifying varying conditions and formulation of tentative conclusions about the effect of various variables of the problem.

3. PRWG-59-c-2 Jeppson, R. W. 1970
Transient flow of water from infiltrometers - formulation of mathematical model and preliminary numerical solutions and analysis of results. Utah Water Res. Lab., Coll. of Engin., Utah State Univ., Logan.

ABSTRACT
The partial differential equation initial-boundary value problems which describe the three-dimensional axisymmetric flow of water from an infiltrometer through partially saturated soil are solved by finite differences using the alternating direction implicit method. Pertinent features which describe the flow characteristics obtained from 34 solutions for varying initial conditions and for 12 soil types are summarized in tables and figures. Relationships between such features as depth of penetration and lateral movement of the wetting front and rate of application and initial hydraulic head or tension in the soil are developed for several of these soil types from analyses of the results.

4. PRWG-59-c-3 Jeppson, R. W. 1970
Formulation and solution of transient flow of water from an infiltrometer using the Kirchoff transformation. Utah Water Res. Lab., Coll. of Engin., Utah State Univ., Logan.

ABSTRACT
This report is a supplement to progress report PRWG-59-c-2 and describes the computer program which implements the Kirchoff Transformation. Use of the Kirchoff Transformation in the formulation of the mathematical problem of partially saturated unsteady flow from an infiltrometer results in improved solution capabilities, particularly for problems in which a portion of the region approaches unit saturation. Also, example solution results are presented.

5. PRWG-59-c-4 Jeppson, R. W. 1970
Determination of hydraulic conductivity--capillary pressure relationship from saturation--capillary pressure data from soils. A description of a computer program for numerically evaluating the Burdine integrals. Utah Water Res. Lab., Coll. of Engin., Utah State Univ., Logan.

ABSTRACT
This report describes a computer program which evaluates the Burdine Integral numerically using discrete data which define the saturation capillary pressure relationship for a given soil. The methodology used in evaluating the Burdine Integrals, as well as a description of the input to and output from the program, are also given.

6. PRWG-59-c-5 Jeppson, R. W. 1970
Solution to transient vertical moisture movement based upon saturation--capillary pressure data and a modified Burdine Theory. Utah Water Res. Lab., Coll. of Engin., Utah State Univ., Logan.

ABSTRACT
Using finite differences and the Crank-Nicolson implicit scheme for solving parabolic type partial differential equations, a computer program has been developed for solving the one-dimensional, vertical movement of water in soils. The formulation of the initial boundary value problem is obtained by introducing a new dependent variable through the Kirchhoff transformation to replace the hydraulic head. Data relating saturation (or moisture content) to the capillary pressure in the soil are used to define the hydraulic properties of the soil which are needed to obtain a solution. The Burdine Theory has been implemented in the program to obtain the needed relationship of hydraulic conductivity to capillary pressure. This formulation and solution method is consistent with the solution method developed earlier for three-dimensional axisymmetric movement of water applied at the surface by a circular infiltrometer, so that comparisons of the solution results from the two different cases would indicate quantitative effects on the flow pattern of the component of radial moisture movement.

A number of solutions have been obtained for several initial moisture contents and for several application rates (including variable rates equal to the intake capacity of the soil), for a soil at the Reynolds Creek Experimental Watershed. Saturation-capillary pressure data for this soil were obtained by the Agricultural Research Service in the laboratory. Laboratory measurements of the hydraulic conductivity corresponding to number of capillary pressures were also obtained. Using the saturation-capillary pressure data in the Burdine equations for evaluating the hydraulic conductivity gives good agreement with these latter laboratory measurements.

The results from these solutions have been used to display the variations of hydraulic head, saturation and hydraulic gradient with time under varying conditions. By contrasting the results from these solutions with those from similar solutions for the axisymmetric case, the effects on the flow patterns due to the radial component of moisture movement have been determined.

7. PRWG-59-c-6 Wei, Chi-Yuan and Jeppson, R. W. 1971
Finite difference solutions of axisymmetric infiltration through partially saturated porous media. Utah Water Res. Lab., Coll. of Engin., Utah State Univ., Logan.

ABSTRACT
Solutions are obtained to the problem of steady-state partially saturated infiltration of moisture applied over a horizontal source circle which moves through homogeneous soils toward a water table. A commonly accepted relationship between relative permeability and capillary pressure has been utilized in conjunction with Darcy's law to formulate the mathematical model. The solutions have utilized an inverse formulation and have been obtained by finite difference. The inverse formulation considers the magnitudes of the cylindrical coordinates r and z as the dependent variables and the potential function Φ and Stokes' stream function Ψ as the independent variables (i.e. the problem is solved for r and z in the $\Phi\Psi$ plane.) The approach used for solving the problems is practical with modern digital computers. The computer output gives the r and z coordinates at each finite difference grid point. These values can readily be plotted in flownet form to show the characteristics of the flow pattern at a glance. From the solution results, the distribution of capillary pressure, relative permeability, or effective saturation over any surface or plane of interest can be obtained. The solutions indicate that significant radial movement of moisture (or spreading effect) occurs causing higher infiltration rate at the edge of the source circle than near the center. The infiltration rate is closely related to various soil parameters which characterize the hydraulic properties of soils. Also presented are several distributions of the relative permeability or effective saturation on the surface, along the axis of symmetry, and on the plane including the axis of symmetry and how these distributions are related to the soil parameters.

8. PRWG-59-c-7 Jeppson, R. W. 1972
Relationships of infiltration characteristics to parameters describing the hydraulic properties of soils. Utah Water Res. Lab., Coll. of Engin., Utah State Univ., Logan.

ABSTRACT
The development of the solution capability, analysis of the finite difference operators, and presentation of solution results are given in this report.

A number of numerical difficulties occurred in attempting to obtain solutions to this layered soil problem. Some of these difficulties, which are a consequence of the nonlinearities in the basic flow equation, could be investigated more adequately by developing a program based on the same mathematical formulation and solution method as the layered, but for the simpler problem, of vertical infiltration through nonlayered soil. The erratic behavior of the finite difference operators, that was discovered for this simpler problem explains why many writers in the literature refer to difficulties they encountered in solving the flow equation for partially saturated groundwater problems. This behavior is described in this report and a method is given to insure convergence.

After developing a computer program for solving a dimensionless formulation of the vertical movement problem, a number of solutions were obtained by varying the dimensionless parameters in the formulation. The solution results have been summarized in graphical form in the latter part of the report to define the influence of soil parameter, and problem specification on such dependent quantities as infiltration capacity, rate of movement of the wetting front, surface saturation and other quantities of interest in watershed studies, irrigation, and other fields concerned with unsaturated moisture movement.

9. PRWG-59-c-8 Jeppson, R. W. 1972
Limitations of some finite difference methods in solving the strongly nonlinear equation of unsaturated flow in soils. Utah Water Res. Lab., Coll. of Engin., Utah State Univ., Logan.

ABSTRACT
This report discusses the limitation of some finite difference methods in solving the strongly nonlinear equation of unsaturated flow in soils. The report is restricted to the hydraulic head based equation of flow, but one might expect similar behavior from the diffusivity form of the equation of flow. To illustrate some of these items, both the transient problem of one-dimensional vertical moisture movements, and the transient problem of three-dimensional but axisymmetric (and therefore, actually two-dimensional) moisture movement from infiltration applied on a circular surface are solved using several finite difference schemes. The considerably different solutions from different schemes points out some of their inadequacies.

10. Rawls, W. J. 1973
Summary of the 1972 infiltration research at the Northwest Watershed Research Center, Northwest Watershed Research Center Report.

ABSTRACT
This report describes the specially designed rainfall simulator-gamma probe infiltrometer and the field procedure used for obtaining pressure saturation data, movement of the wetting front and the runoff rate. Enclosed in the appendix are the soil profile descriptions, dry bulk densities, and the runoff and infiltration data obtained from the three areas in Reynolds Creek Watershed.

Presentation of Above
Rawls, W. J. 1973
Infiltration Studies pres. at ARS-SCS Western Hydrol. Workshop, August 20-24, Boise, Idaho.

11. Will, Gregory R. 1973
Rainfall simulator. Masters Thesis, Oregon State Univ., 70 pp.

ABSTRACT
A large rainfall simulator was used to study infiltration on six soil plots. Water content and capillary pressure were measured during steady rainfall at rates less than required to produce runoff. The equipment and procedures used to make these measurements are discussed. Water content and capillary pressure data obtained as a function of time were combined to produce the in situ water holding capacity curve for the profile. The results were compared with data obtained from soil samples using conventional laboratory techniques.

Infiltration capacity curves were also obtained for these soils using high rates of rainfall. The infiltration capacity curves for the plots are compared using scaled variables.

12. Brooks, Royal H., Paul J. Leclercq, Richard R. Tebbs, and Walter J. Rawls 1974
Axisymmetric infiltration. Water Resources Res. Inst. Report 22, Oregon State Univ., Corvallis, Oregon. 61 pp.

ABSTRACT
This report describes in detail a rapid method for measuring capillary pressure saturation curves for both imbibition and drainage. A functional relationship between capillary pressure

and saturation for imbibition is proposed that includes the properties obtained from the drainage capillary pressure-saturation curve. Finally, the infiltration under a circular infiltrometer is computed from a mathematical model and compared with experimental data. The solutions were obtained using both imbibition and drainage functions. The solutions are presented in terms of scaled variables to show the effect of hydraulic properties upon infiltration rate and advance of the wetting front.

13. Jeppson, R. W., 1974.
Axisymmetric infiltration in soils, I. Numerical techniques for solution, Jour. Hydrol., 23: 111-130.

ABSTRACT
Numerical solutions are obtained to the transient, three-dimensional axisymmetric, unsaturated moisture movement through homogeneous soil due to infiltration over a horizontal circular surface area. The paper is divided into two parts. The present part deals with techniques for numerical solutions, the difficulties in achieving such solutions due to the strong nonlinearities of the equation of flow, and procedures which minimize such difficulties. In this part three adaptations of the Crank-Nicolson method, and three variations of the alternating direction implicit (ADI) method are studied and their solutions compared. Only those methods which evaluate the nonlinear coefficients on the advanced time planes fully implicitly yield solution in close agreement. When dealing with the Crank-Nicolson adaptations, fully implicitly implies solving a system of nonlinear equations by the Newton-Raphson iteration, and in the ADI methods the coefficients causing the nonlinearities must be iteratively corrected a number of times. A single predictor is not adequate. One valid adaptation of the Crank-Nicolson method produces a system of nonlinear equations, which is much easier to solve than the other, and the third adaptation is valid only for constant coefficients, and it produces solutions grossly in error, and thus illustrates the influence of the nonlinearity on the equation of flow.

14. Jeppson, R. W. 1975
Axisymmetric infiltration of soils, II. Summary of infiltration characteristics related to problems specification. Jour. Hydrol., (In press).

ABSTRACT
Numerical solutions are obtained to the transient, three-dimensional axisymmetric, unsaturated moisture movement through homogeneous soil due to infiltration over a horizontal circular

surface area. The paper is divided into two parts. The present part compiles solutions from a number of problems in graphs relating some items of interest in infiltration to such problem specifications as size of circle of application and parameters describing the hydraulic properties of unsaturated soils.

15. Jeppson, R. W., W. J. Rawls, W. R. Hamon, and D. L. Schreiber
1975
Use of axisymmetric infiltration model and field data to determine hydraulic properties of soils. Water Resources Research (In press).

ABSTRACT
A numerical model is described for solving axisymmetric infiltration problems. The model uses saturation-capillary pressure data and a modified Burdine equation to develop reasonable estimates of relative hydraulic conductivity. A specially designed infiltrometer and a field data collection system, which provide infiltration-capacity, saturation-time, and saturation-capillary pressure data, are also described. The numerical solutions were fitted to the field data to define the hydraulic properties of the soil. Close agreement was found between the numerical model solutions and field measurements for two sites on the Reynolds Creek Experimental Watershed in southwestern Idaho. A feasible method was derived for determining the hydraulic properties of surface soils under natural conditions.

16. Penton, V. E., W. R. Hamon, and W. J. Rawls
Rainfall Simulator-Gamma Probe Infiltrometer. (In preparation for publication in Water Resources Research.)

ABSTRACT
A detailed description of the design and development of the rainfall simulator-gamma probe infiltrometer is given, along with detailed working drawings and pictures.

EVAPOTRANSPIRATION

Title: Natural evaporation from sagebrush rangelands, alfalfa, and stockponds in a semiarid environment

Personnel Involved:

C. L. Hanson, Agr. Engr.	Plan programs and procedures; design and construct facilities for evaporation studies. Perform analyses and summarize results.

Date of Initiation: November 1968

Expected Termination Date: Continuing

INTRODUCTION

A complete understanding of the evaporative process is essential when developing predictive relationships for the evapotranspiration component in definable soil vegetation complexes under a particular level of management. The Northwest Watershed Research Center is conducting evapotranspiration studies designed for measuring and predicting evapotranspiration under sparse vegetative cover and unsaturated surfaces.

Objectives:

1. To determine the evaporative loss of water from sagebrush rangelands, irrigated alfalfa, and stockponds, while observing pertinent meteorological parameters and the soil moisture status.

2. To develop, for predictive purposes, relationships for associating the evaporative loss with meteorological parameters, type and degree of surface cover, soil moisture, and potential evaporative demand.

PROGRESS

Two lysimeters at the Lower Sheep Experimental Site were in operation from May 9 through September 9, 1974. The daily evapotranspiration from these lysimeters is being analyzed at the present time. Preliminary results, however, show that the May evapotranspiration was about 0.05 inches per day, decreasing to 0.02 per day in July and August and then increasing to 0.04 inches per day in September and October when the sagebrush started its fall growth.

Weekly neutron soil-water measurements were taken in the lysimeters. The soil-water data are now being processed, along with the other soil-water measurements on the watershed.

The data from the two lysimeters at the Reynolds Mountain Site were obtained from the meteorological telemetering system. This system did not give the necessary resolution and, thus, a new printer has been obtained for the 1975 season.

Leaf area index (LAI) was measured periodically on the four lysimeters with the results listed in Tables 1 and 2. LAI on the Lower Sheep Creek lysimeters was about 0.2 in mid-April and then increased to about 0.7 by early June. LAI then decreased through July and August and increased some in September and October when the sagebrush started fall growth. This increase in LAI is associated with increased evapotranspiration during September and October. The LAI on the Reynolds Mountain lysimeters was at a maximum in June and decreased through August. The LAI increased on the north lysimeter, but decreased slightly on the south lysimeter in early October. The LAI values at Reynolds Mountain were not greatly different from the Lower Sheep lysimeters.

The LAI data are being used in the initial evapotranspiration model development.

The hydrology model being adapted for the Reynolds Creek Watershed requires an estimate of daily Class A Pan evaporation. Since there is no pan information available for the period to be modeled it was necessary to develop an equation to estimate daily Class A Pan evaporation. The estimating equation developed was based on Class A Pan data and the associated meteorological data from two western South Dakota locations. The equation developed for May 1 through October 15 is:

$$EV = R(-0.70 + 0.02\,T) + 0.001\,W$$

where:

EV = daily Class A Pan evaporation (inches/day)

R = daily solar radiation (Langleys/day/1486)

T = mean daily temperature (°F)

W = wind run (miles/day).

TABLE 1.--Leaf area index (LAI) on the lysimeters at Lower Sheep Creek study areas, 1974

Date	4/12	4/25	5/3	5/22	6/6	6/18	7/2	8/21	9/10	10/3
Vegetation										
	East Lysimeter									
Grasses	.20	.32	.32	.30	.12	.08	.03	---	---	---
Forbs	.03	.12	.02	.03	.08	.03	---	---	---	---
Sagebrush	---	---	.11	.26	.51	.45	.45	.12	.20	.23
TOTAL	.23	.44	.45	.59	.71	.56	.48	.12	.20	.23
	West Lysimeter									
Grasses	.17	.27	.34	.26	.12	.03	.01	---	---	---
Forbs	---	.11	.04	.08	.05	.04	.01	---	---	---
Sagebrush	---	---	.17	.30	.56	.41	.32	.17	.24	.25
TOTAL	.17	.38	.55	.64	.73	.48	.34	.17	.24	.25

TABLE 2.--Leaf area index (LAI) on the lysimeters at the Reynolds Mountain study site, 1974

Date	6/17	7/2	8/21	10/3	6/17	7/2	8/21	10/3
	North Lysimeter				South Lysimeter			
Vegetation								
Grasses	.26	.17	.04	---	.27	.18	.08	---
Forbs	.04	.03	---	---	.13	.19	.01	---
Sagebrush	.39	.24	.23	.34	.41	.27	.19	.25
TOTAL	.69	.44	.27	.34	.81	.64	.28	.25

SIGNIFICANT FINDINGS

An equation was developed to estimate daily Class A Pan evaporation from meteorological data.

WORK PLAN FOR FY 76

The goal is to develop a basic evapotranspiration model for rangeland watershed using lysimeter data and supporting information from the neutron soil-water measuring program. The 1974 data will be used to develop an initial model and it will be necessary to obtain additional information from the lysimeters and soil-water program to test the constants in the model. The model will then be used in a watershed hydrologic modeling program.

The lysimeters at both the Lower Sheep Creek and the Reynolds Mountain Experiment Sites, along with a neutron soil-water measuring program, will be continued in 1976.

REPORTS AND PUBLICATIONS

Hanson, C. L.
Model for predicting evapotranspiration from native rangeland in the Northern Great Plains. (Submitted to the Trans. of ASAE).

WATER QUALITY

Title: Water quality characteristics of the hydrologic flow regime of the Reynolds Creek Experimental Watershed

Personnel Involved:

G. R. Stephenson, Geologist	Responsible for coordinating activities with cooperators. Design collection network and responsible for project completion.
J. F. Zuzel, Hydrol. Tech.	Responsible for statistical analysis of data and shares the responsibility for aquatic sampling.
C. M. Rountree, Biol. Tech. (Resigned September 1974)	Responsible for collection of water samples, aquatic samples, and laboratory analyses.

Date of Initiation: October 1972

Expected Termination Date: Continuing

INTRODUCTION

In recent years, because of the increased concern for the quality of our environment, many agricultural practices have come under close scrutiny as potential sources of air and water pollution.

Several agricultural practices are known to have contributed to pollution of surface and ground-water resources. Feedlot operations under certain conditions do contribute to increasing nitrate content of adjacent surface and ground water. Heavy grazing on open range usually compacts the soil, reduces infiltration, and seriously reduces the vegetative cover, increasing runoff. Increased turbidity and contribution of sediment and nutrients to the streams are often the result. Irrigation usually contributes heavily to total salt and nitrate-nitrogen content downstream. However, not all agricultural operations are detrimental.

Information is needed on the water quality characteristics of rangeland watersheds under natural conditions and various land management practices. The Reynolds Creek Experimental Watershed offers an excellent opportunity to study water quality characteristics related to

several of the above-mentioned problems. No commercial fertilizers or pesticides have been used on the watershed. Herbicides were used infrequently for sagebrush control, but not since 1965.

With the present distribution of hydrologic networks throughout the watershed, sampling of both surface and subsurface flow for water quality analyses can easily be accomplished. The water quality constituents can be related to the hydrology of the system, particularly the properties of the water, the distribution, and the circulation.

The BLM has expressed need for more information on water quality changes influenced by various land management practices. As more rangeland is being used for recreation, this information becomes more important.

Objectives:

To determine water quality characteristics of the hydrologic flow regime of the Reynolds Creek Experimental Watershed as related to:

1. Concentrations of cattle on local areas of rangeland and quasi-feedlot conditions,

2. Irrigation return flow, and

3. Natural soil and geologic conditions.

PROGRESS

To comply with the 1975 FY Work Plan, increased sampling was necessary to more accurately determine the effect concentrations of cattle on open range have on the quality of water in Reynolds Creek. A total of 384 samples were collected at 14 sites during the year and analyzed for total and fecal coliform bacteria. In addition to the increase in bacteriological quality studies, the chemical and physical quality studies were continued, with 112 samples collected at seven sites. Figure 1, an index map of the Reynolds Creek Watershed, gives the locations of all sampling sites. Table 1 gives a general review of the water quality characteristics resulting from this year's analyses.

In general, streamflow during late winter and early spring was somewhat greater than the previous year. However, the hot and dry late summer and fall months caused flow to cease at several sampling sites at this time. By mid October, water was flowing again at all sampling sites.

TABLE 1.--Water quality characteristics, Reynolds Creek Watershed sampling sites

Parameter	Units	No. of Samples	Maximum	Minimum	Average
		REYNOLDS MOUNTAIN SPRING (176S12)			
pH	units	13	7.70	6.58	6.99
Conductivity	µmhos	13	47	22	35.53
Dissolved solids	mg/l	13	30.55	14.30	23.10
Calcium	mg/l	13	4.61	2.81	3.69
Magnesium	mg/l	13	.61	.12	.36
Sodium	mg/l	13	3.22	1.15	1.65
Phosphorus	mg/l	13	.03	.01	.02
Nitrate	mg/l	13	2.78	.84	1.77
SiO_2	mg/l	12	12.10	9.00	10.83
Sodium Adsorption Ratio	ratio	13	.43	.17	.25
Suspended solids	mg/l	13	22	0	6.38
Total coliform	cts/100 ml	22	16	0	1.82
Fecal coliform	cts/100 ml	22	2	0	.36
		REYNOLDS MOUNTAIN WEIR (166074)			
pH	units	8	7.82	7.18	7.44
Conductivity	µmhos	8	52	28	40.13
Dissolved solids	mg/l	8	33.80	18.20	26.08
Calcium	mg/l	8	5.21	3.21	3.89
Magnesium	mg/l	8	1.46	.24	.85
Sodium	mg/l	8	4.37	2.07	3.19
Phosphorus	mg/l	8	.06	.03	.05
Nitrate	mg/l	8	.10	.03	.05
SiO_2	mg/l	8	26.80	15.00	21.30
Sodium Adsorption Ratio	ratio	8	.44	.30	.38
Suspended solids	mg/l	8	20	0	8
Total coliform	cts/100 ml	13	5150	52	1783.38
Fecal coliform	cts/100 ml	13	>3500	6	634.08
		DEMOCRAT (155019)			
pH	units	15	8.14	7.56	7.81
Conductivity	µmhos	15	107	41	80.47
Dissolved solids	mg/l	15	69.60	26.65	52.44
Calcium	mg/l	15	13.43	4.01	9.33
Magnesium	mg/l	15	2.67	.73	1.78
Sodium	mg/l	15	5.98	2.99	4.47
Phosphorus	mg/l	15	.13	.02	.06
Nitrate	mg/l	15	.71	.03	.17
SiO_2	mg/l	15	23.50	15.30	18.64
Sodium Adsorption Ratio	ratio	15	.41	.31	.36
Suspended solids	mg/l	15	28	0	9.87
Total coliform	cts/100 ml	31	2180	0	585
Fecal coliform	cts/100 ml	31	1160	0	55.19
		ABOVE DOBSON (135018)			
Total coliform	cts/100 ml	31	3950	24	847.52
Fecal coliform	cts/100 ml	31	475	0	74.48

TABLE 1.--Water quality characteristics, Reynolds Creek Watershed sampling sites (Cont'd)

Parameter	Units	No. of Samples	Maximum	Minimum	Average
		DOBSON (135017)			
pH	units	19	8.10	7.44	7.87
Conductivity	µmhos	19	177	71	127
Dissolved solids	mg/l	19	115.05	46.15	82.55
Calcium	mg/l	19	20.44	7.41	14.25
Magnesium	mg/l	19	7.05	2.08	4.65
Sodium	mg/l	19	7.82	3.45	5.73
Phosphorus	mg/l	19	.08	.03	.05
Nitrate	mg/l	19	.22	.02	.09
SiO_2	mg/l	19	33.80	24.60	28.54
Sodium Adsorption Ratio	ratio	19	.39	.28	.35
Suspended solids	mg/l	19	28	0	12.79
Total coliform	cts/100 ml	31	3280	12	902.94
Fecal coliform	cts/100 ml	31	1080	0	156.77
		BELOW DOBSON (135008)			
Total coliform	cts/100 ml	31	>3500	0	712.42
Fecal coliform	cts/100 ml	31	450	0	70.52
		TOLLGATE (116083)			
pH	units	19	8.34	7.58	7.96
Conductivity	µmhos	19	199	70	140.84
Dissolved solids	mg/l	19	699.40	46.80	215.83
Calcium	mg/l	19	20.44	7.21	14.74
Magnesium	mg/l	19	8.27	2.19	5.25
Sodium	mg/l	19	9.20	3.45	6.44
Phosphorus	mg/l	19	.15	.02	.07
Nitrate	mg/l	19	.34	.01	.09
SiO_2	mg/l	19	33.00	23.00	26.39
Sodium Adsorption Ratio	ratio	19	.60	.29	.38
Suspended solids	mg/l	19	68	0	15.10
Total coliform	cts/100 ml	31	3400	45	701
Fecal coliform	cts/100 ml	31	325	0	55.87
		GABICA (106018)			
Total coliform	cts/100 ml	31	1800	10	452.87
Fecal coliform	cts/100 ml	31	236	0	38
		NETTLETON (087082)			
Total coliform	cts/100 ml	30	6750	0	1464.77
Fecal coliform	cts/100 ml	30	1264	0	133.87
		TYSON (077071)			
Total coliform	cts/100 ml	23	>3500	260	926.87
Fecal coliform	cts/100 ml	23	552	0	172.83

TABLE 1.--Water quality characteristics, Reynolds Creek Watershed sampling sites (Cont'd)

Parameter	Units	No. of Samples	Maximum	Minimum	Average
		LOWER REYNOLDS (056047)			
pH	units	19	8.58	7.52	8.06
Conductivity	μmhos	19	1183	138	702.89
Dissolved solids	mg/l	19	768.95	89.70	402.28
Calcium	mg/l	19	74.75	12.83	46.22
Magnesium	mg/l	19	53.25	4.74	15.25
Sodium	mg/l	19	162.07	9.43	73.70
Phosphorus	mg/l	19	.27	.03	.10
Nitrate	mg/l	19	.43	.01	.14
SiO_2	mg/l	19	40.10	26.20	33.32
Sodium Adsorption Ratio	ratio	19	4.07	.57	2.26
Suspended solids	mg/l	19	104	2	23.37
Total coliform	cts/100 ml	31	6960	75	1078.58
Fecal coliform	cts/100 ml	31	3500	0	504.74
		MACKS CREEK (046084)			
Total coliform	cts/100 ml	27	7200	30	914.52
Fecal coliform	cts/100 ml	27	2264	0	163.44
		SALMON (036098)			
Total coliform	cts/100 ml	29	2850	100	823.62
Fecal coliform	cts/100 ml	29	465	0	61.10
		OUTLET WEIR (036068)			
pH	units	19	8.74	6.90	8.07
Conductivity	μmhos	19	1490	152	699.11
Dissolved solids	mg/l	19	968.50	98.80	457.05
Calcium	mg/l	19	83.97	14.83	44.12
Magnesium	mg/l	19	34.04	4.74	18.61
Sodium	mg/l	19	157.24	10.80	81.87
Phosphorus	mg/l	19	.24	.02	.11
Nitrate	mg/l	19	1.82	.05	.58
SiO_2	mg/l	19	39.00	28.40	33.86
Sodium Adsorption Ratio	ratio	19	3.95	.63	2.44
Suspended solids	mg/l	19	62	0	26.89
Total coliform	cts/100 ml	31	>3500	0	889.84
Fecal coliform	cts/100 ml	31	228	0	73.39

Chemical Quality:

The following discussion of chemical quality on Reynolds Creek is set up for comparison with last year's results. A comparison of selected chemical parameters is given in Figures 2 and 3 for two sites, one characterizing streamflow from open range and one from irrigation return flow. As noted in last year's results, marked changes occur in levels of concentrations at the lower Reynolds site during the irrigation season, while levels of concentration at the Tollgate site (no irrigation return flow) remain relatively constant.

The sodium adsorption ratio remains low, indicating that sodium is not a dominating alkali hazard in the irrigation return flow waters. The conductivity values increased considerably during the irrigation season, indicating a salinity increase in the lower reaches of Reynolds Creek. Sulphate, though not a hazardous constituent, is prominent during irrigation return flow, as can be seen in Figure 2. The major source of sulphates, as noted in Figure 4, is isolated in one area of the watershed (Macks Creek Drainage Basin), where it is flushed from soils developed from lake sediment evaporites containing gypsum.

Phosphates seem to be related only to increases in streamflow and suspended sediments (Figure 3), and are derived from natural sources, such as the lake sediments. The higher nitrate readings found at the Reynolds Mountain spring and Reynolds Outlet Weir are derived from soluble organic materials. No commercial fertilizers are used on the watershed.

Based, then, on 1974 data under slightly different hydrologic conditions, the chemical quality of Reynolds Creek water shows increases in chemical concentrations during the irrigation season, but is diluted rapidly at the end of the irrigation season by increased precipitation and runoff, and decreased irrigation return flow. There remains no evidence to show that any appreciable deterioration in the chemical quality of Reynolds Creek water results from grazing of livestock on open range.

Physical Quality:

Suspended sediment concentrations for these sampling sites were very low throughout Reynolds Creek. The spring runoff from snowmelt was slow and caused no major flooding. Maximum, minimum, and average values of suspended sediment for each site for those sampling dates are given on Table 1. Additional sediment information is given in the Runoff and Sediment section.

Bacteriological Quality:

The bacteriological quality of the Reynolds Creek water appears to be related directly to the presence or absence of livestock either on open range or concentrated in fields adjacent to the channel.

Figure 5 shows the plotting of total and fecal coliform bacteria counts during the year at three sites along Reynolds Creek. Reynolds Mountain Weir and below-Dobson sites are both on open range, and Lower Reynolds is located in an area where cattle are kept during the winter months. Cattle are generally taken out of the fields and moved to the range in April-June. The Reynolds Mountain and below-Dobson sites show the effects of cattle reaching these areas in June and remaining there until October. The Reynolds Mountain site went dry (no flow) in late August, remaining dry until late October. When runoff and subsurface flow started, the bacteria counts were extremely high and remained high into December under snow cover before starting to decrease.

The Lower Reynolds site illustrates the removal and return of cattle to the field. Cattle were concentrated in this field in late April, before being taken to open range.

The increased sampling frequency and sites this year have shown the direct relationship between the activity of cattle and the bacteriological quality of Reynolds Creek water.

Aquatic Invertebrates:

Aquatic samples were collected at four sites three times during the year. However, as specified in last year's annual report, additional sampling would be necessary in September and October to define peak totals. This was not done this year because of the resignation of the Biological Technician.

Analyses of the data collected this year correspond well with last year's data, but still do not show the peak accumulations during the fall months. The presentation of aquatic data in the 1974 annual report remains appropriate.

Water Quality Model:

Data collected and analyzed from this study are presently being adopted for testing of the Idaho Department of Water Resources water quality model. This particular model considers hydrologic, biologic, chemical, and hydraulic parameters for prediction of changes of water quality in one-mile segments of a particular channel. We are presently trying to make the proper adaptations necessary between the data and the model for its application to Reynolds Creek.

Ground Water Investigations:

No additional work was done in this particular study this year.

SIGNIFICANT FINDINGS

1. Analyses of the 1974 data show that any reduction in chemical quality of Reynolds Creek water is the result of irrigation return flow. Increased salinity during the irrigation season results in a high salinity hazard for the lower reaches of Reynolds Creek. The sodium (alkali) hazard remains low, however.

2. Sources of several of the naturally occurring ions, such as sulphate, nitrate, and phosphate were determined. As no commercial pesticides, herbicides, or fertilizers were used on the watershed, these particular ions were found to originate from naturally occurring isolated sources. The phosphorus and sulphate ions originate from lake sediment deposits and the nitrate ions from soluble organic materials in the soils.

3. Any deterioration in the bacteriological quality of Reynolds Creek water is the direct result of the presence of concentrations of cattle and other livestock. At certain sampling sites during the year, fecal coliform counts exceed those suggested by the State Health Department for free-flowing streams.

WORK PLAN FOR FY 76

The present sampling network will be maintained for monitoring chemical quality of Reynolds Creek. Specific attention will be given to chemical changes related to changes in the flow regime.

The present bacteriological quality network will be maintained with increased samples collected during selected 24-hour periods at sites on open range during the grazing season. This will enable us to determine the variation in bacteria activity at a specific site as related to various times of the day. Accurate numbers of livestock in any one grazing unit will be closely monitored with BLM records.

Additional aquatic invertebrate samples will be collected during the late summer and fall months to determine more precisely peak totals.

The Idaho Department of Water Resources water quality model will be tested on Reynolds Creek.

REPORTS AND PUBLICATIONS

Stephenson, G. R., and J. F. Zuzel 1975
Chemical analyses of a ground-water flow system. ABSTRACT. Approved for presentation at Geol. Soc. America Meeting, Boise, Idaho, May.

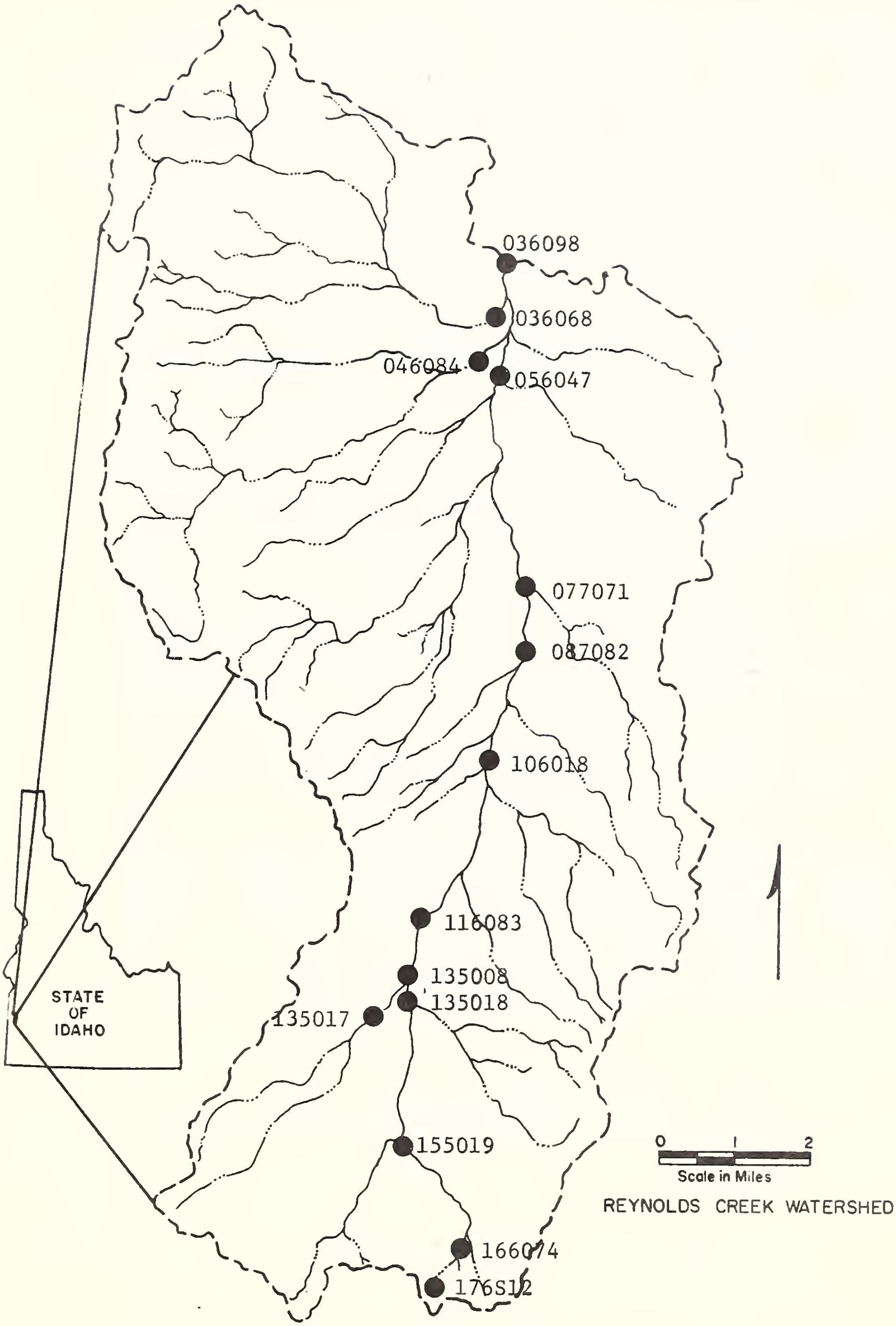

Figure 1. Index Map of Water Quality Sampling Sites, Reynolds Creek Watershed.

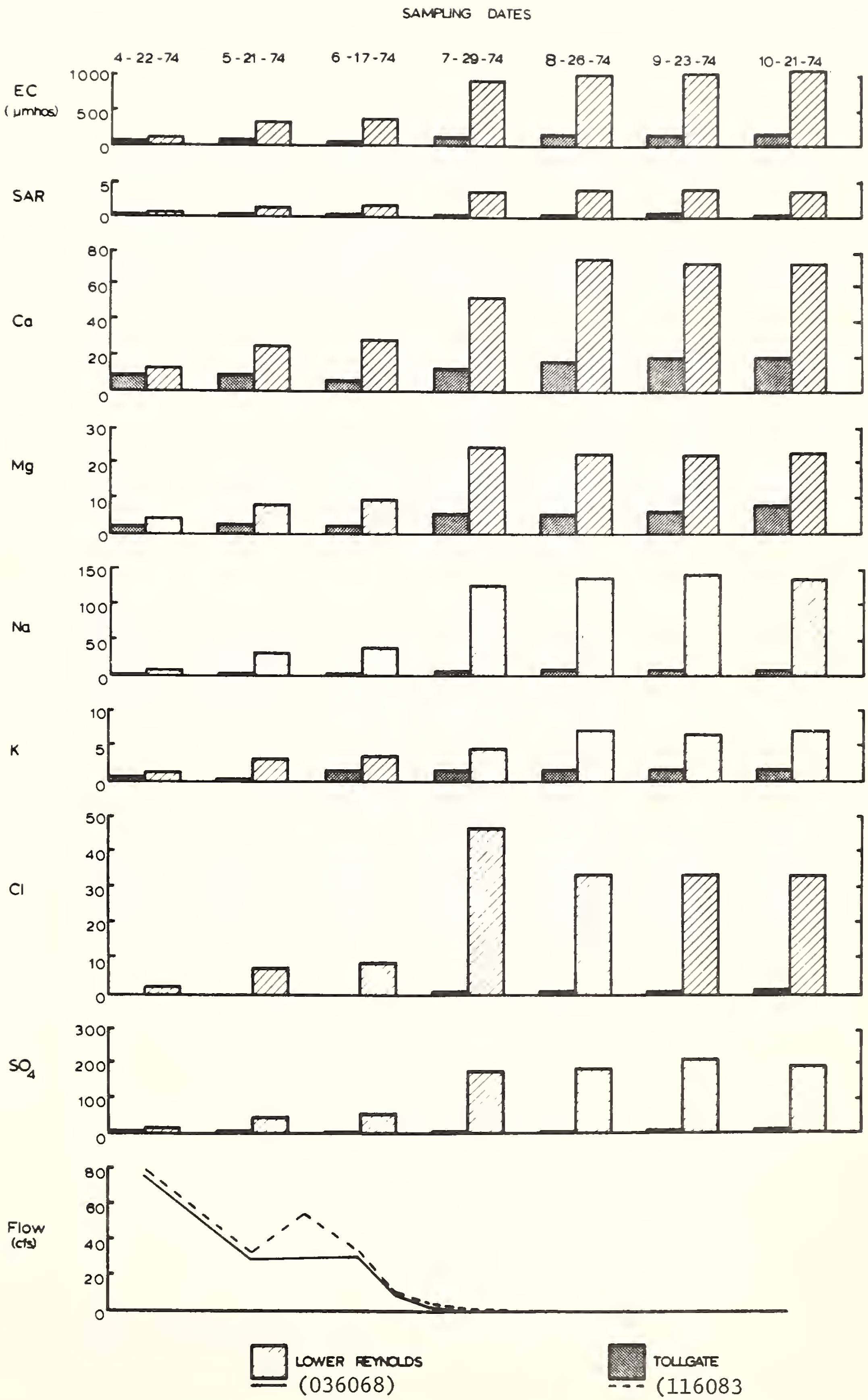

Figure 2. Major Chemical Constituents (mgl) and Channel Flow at Sites on Reynolds Creek

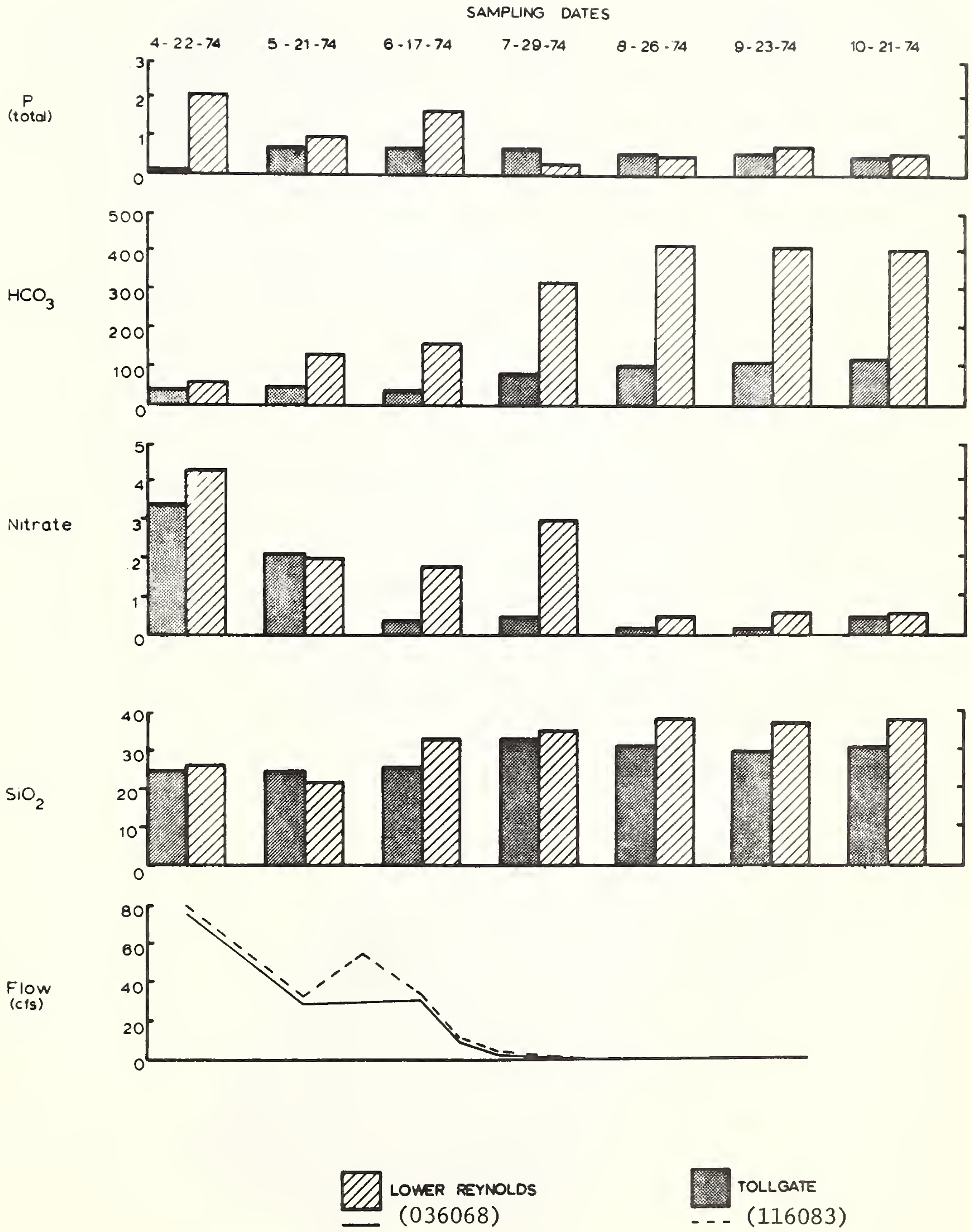

Figure 3. Major Chemical Constituents (mgl) and Channel Flow at two Sites on Reynolds Creek

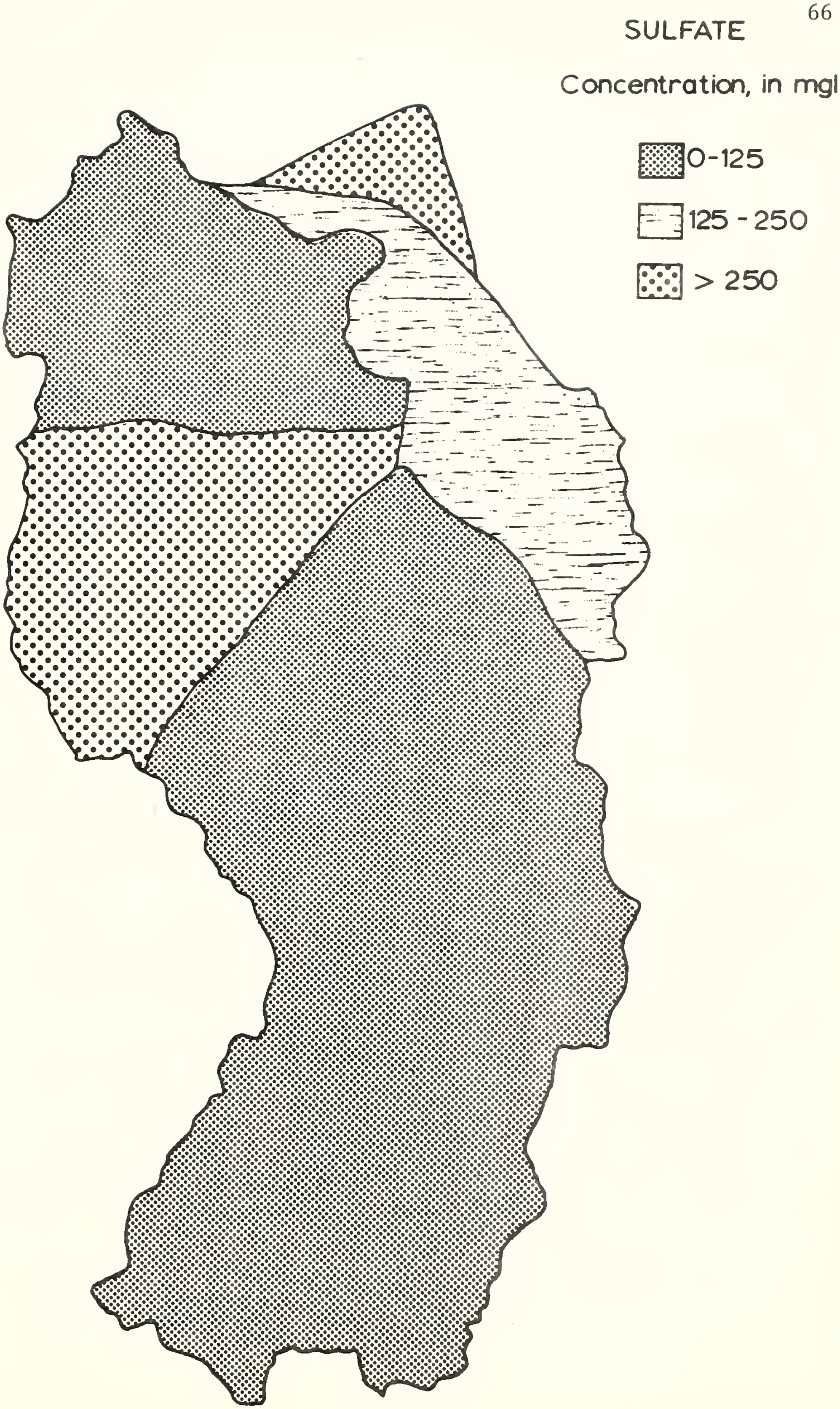

Figure 4. Major Sources of Sulphate ions on Reynolds Creek drainage

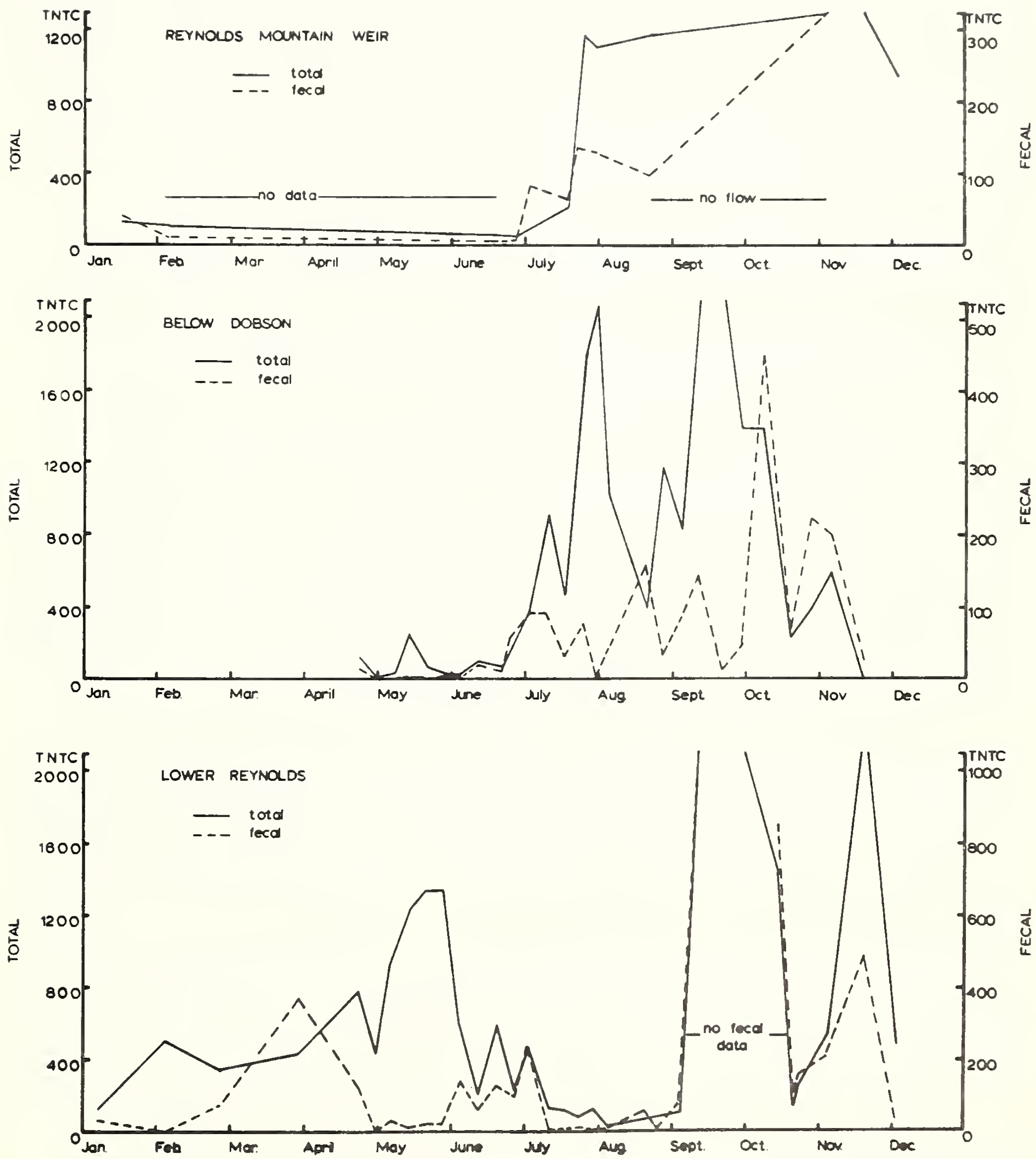

Figure 5. Total and fecal coliform bacteria counts at three sites along Reynolds Creek

RUNOFF AND SEDIMENT

Title: Sediment yield and runoff from rangeland watersheds

Personnel Involved:

C. W. Johnson, Res. Hydr. Engr.	Plan programs and procedures; design and construct facilities for sediment studies; perform analyses and summarize results.
G. R. Stephenson, Geologist	Determine geologic and geomorphic parameters related to sediment yield.
C. L. Hanson, Agr. Engr.	Test various components in sediment models most applicable to rangelands.
R. L. Engleman, Hydrol. Tech.	Perform data compilation and assist in analyses.

Date of Initiation: September 1, 1969

Expected Termination Date: Continuing

INTRODUCTION

Information on sediment yield is almost entirely lacking for millions of acres of predominantly sagebrush rangeland under government land management and private ownership in the Northwestern United States. There is a growing concern for soil losses from intensively grazed rangelands, sediment damage to reservoirs, and erosion of stream channels.

Most rangeland watersheds in the Intermountain Northwest have large areas of relatively steep hillslope topography, and these areas need to be delineated for treatment to reduce erosion. Also, sediment yield information is needed for evaluating the benefits of watershed management and land treatment programs of the Bureau of Land Management and Soil Conservation Service.

Range sites found in the Reynolds Creek Experimental Watershed represent a large percentage of the rangeland in the Northwest, and studies of sediment yield are essential for developing sound management practices and planning appropriate multiple use of these lands. Good land management decisions require information on how vegetative changes, fencing, and land use alter the sediment yield potential of rangeland watersheds.

The sources of these sediments need to be determined so that research data can be used to predict sediment yield for ungaged areas in terms of available information on soils, climate, physiography, and use. Research is also needed to adapt the Universal Erosion Equation to rangelands.

Objectives:

1. To determine the relationships between sediment yield and variables describing hydraulic and hydrologic factors and site and watershed characteristics that influence sediment yield.

2. To test presently used erosion and sediment yield procedures, utilizing Reynolds Creek Watershed Data.

3. To develop and test improved erosion and sediment yield prediction procedures for rangeland watersheds in the northwest.

Suspended and bedload sediment yields from plots, channels, and watersheds are measured by pumping sediment samplers, splitting devices, catchments, and hand sampling. Plots, microwatersheds, and watersheds are located on various soil types in different precipitation zones. A wide range of slope length, slope area, aspect, and relief ratio is represented. Rainfall intensity and duration data are available from a network of precipitation gages, and snow data are available from snow courses, snow pillows, and other snow-measuring sites. Also, data on cover, topography, and soil factors (including frost depths), which influence erosion and sedimentation, are available through other investigations at the Northwest Watershed Research Center.

PROGRESS

Runoff and sediment-measuring facilities

Plots and watersheds instrumented for runoff and sediment measurement are listed in Table, locations are shown in Figure 1. A detention box for measuring sediment yield from the Lower Sheep Creek Watershed (33 acres) was completed in 1974. Also, the sediment deposit was removed from the Murphy Creek Weir pond to allow measurement of sediment from this 306-acre watershed.

Suspended sediment pumping samplers were improved and serviced to increase their reliability and additional bedload samplers were procured for use during flood events in 1975.

TABLE 1.--Plots and watersheds instrumented for runoff and sediment measurement, Reynolds Creek Watershed, December 1974.

Watershed or Plot NAME	No.1/	Drainage Area (Acres)	Runoff Measuring Device	Suspended Sediment Sampler	Bedload Sediment Sampler
Reynolds Creek Outlet	1	57700	SCOV Weir	P.S. 67 Pump	Helley-Smith
Salmon Creek	2	8990	Drop-Box Weir	Hand Held	Helley-Smith
Murphy Creek	3	306	Drop-Box Weir	Hand Held	Detention Pond
Macks Creek	4	7846	Drop-Box Weir	P.S. 67 Pump	Helley-Smith
Summit	5	205	Drop-Box Weir	Gravity Flow	Detention Pond
Flats	6	2.24	V-Notch Weir	Single Stage	Detention Tank
Nancy Gulch	7	3.1	V-Notch Weir	Single Stage	Detention Tank
Whiskey Hill	8	119	V-Notch Weir	Hand Held	Detention Pond
Lower Sheep	9	33	Drop-Box Weir	Hand Held	Detention Box
Upper Sheep	10	63.4	Drop-Box Weir	Chickasha Pump	Detention Box
Reynolds Tollgate	11	13453	Drop-Box Weir	P.S. 67 Pump	Helley-Smith
Reynolds Mountain	12	100	V-Notch Weir	Chickasha Pump	Detention Box
PLOTS		ALL PLOTS: 14 feet wide, 72.6 feet long V-Notch Weirs, single stage samplers, overflow sample tank, and settling tank			
Summit	5				
Windy Point	13				
Nancy Gulch	7				
Upper Sheep	10				
Nettleton	14				
Reynolds Mountain	12				

1/ Numbers designate locations of weirs and plots in Figure 1.

Precipitation and runoff

Table 2 shows monthly precipitation and runoff for the 1974 water year, compared with the averages for the period of record at selected stations. October through March precipitation at the Reynolds Weather Station was about 20 percent above average, which resulted in the highest snow accumulation of record at snow survey stations. In contrast, the April through September precipitation was only 1.22 inches, about 25 percent of average. The yearly runoff volumes at the Reynolds Creek Outlet, Reynolds Tollgate, and the Reynolds Mountain Weirs were about 137, 127, and 127 percent of average, respectively. Major runoff events occurred at the Outlet Weir January 12-18, March 12-17, and March 28-30, 1974. Table 3 shows yearly peak streamflow rates at the Outlet, Tollgate, and Reynolds Mountain Weirs for the period of record. The monthly distribution of peak events exceeding various streamflow rates at the Outlet Weir is shown in Table 4.

TABLE 2.--Precipitation and runoff at selected stations, Reynolds Creek Watershed, 1974 water year.

Month	Precipitation 1/		Runoff					
			Outlet Weir 2/		Tollgate Weir 3/		Reynolds Mtn. 4/	
	13-Year Average	1974 Water Year	12-Year Average	1974 Water Year	9-Year Average	1974 Water Year	12-Year Average	1974 Water Year
	(In)	(In)	(In)	(In)	(In)	(In)	(In)	(In)
Oct.	.87	.41	.02	.01	.09	.07	.14	.10
Nov.	1.29	1.74	.05	.05	.17	.17	.26	.25
Dec.	1.28	1.88	.20	.17	.24	.26	.43	.20
Jan.	1.40	1.14	.50	.49	.82	.86	.49	.53
Feb.	.58	.49	.30	.21	.54	.31	.51	.26
Mar.	.78	2.28	.52	1.20	1.24	2.03	.70	.82
Apr.	.98	.28	.61	1.04	1.85	2.97	2.98	3.48
May	.76	.16	.60	.71	3.24	3.65	10.17	12.37
June	1.73	.32	.31	.40	1.46	1.96	4.63	7.78
July	.16	.28	.04	.06	.25	.39	.49	.71
Aug.	.72	.18	.02	.02	.05	.06	.10	.09
Sept.	.49	0	.01	.01	.04	.03	.08	.05
Water Year	11.04	9.16	3.18	4.37	9.99	12.76	20.98	26.64

1/ Reynolds Weather Station, 076059, Weather Service Standard Gage, Elevation 3915 ft.

2/ Reynolds Creek Outlet Weir, Station 036068, Watershed Area 90 sq. mi., Weir Elevation 3600 ft.

3/ Reynolds Creek Tollgate Weir, Station 116083, Watershed Area 21 sq. mi., Weir Elevation 4600 ft.

4/ Reynolds Mountain Watershed, Station 166076, Drainage Area 100 a., Weir Elevation 6600 ft.

TABLE 3.--Yearly peak streamflow rates and dates of occurrence, selected Reynolds Creek Watershed Stations, 1963-74.

	Reynolds Creek Outlet Weir		Reynolds Creek Tollgate Weir		Reynolds Mountain East Weir	
Water Year	Date	Peak Flow	Date	Peak Flow	Date	Peak Flow
		(cfs)		(cfs)		(cfs)
1963	Jan. 31	2331	--	--	Apr. 29	4.16
1964	Jan. 25	188	--	--	May 16	3.60
1965	Dec. 23	3850	--	--	Dec. 23	10.70
1966	Apr. 1	59	Apr. 1	59	May 5	1.43
1967	June 7	265	June 7	288	May 22	5.44
1968	Feb. 21	327	Feb. 21	186	Aug. 10	1.48
1969	Jan. 21	900	Jan. 21	405	May 12	3.88
1970	Jan. 27	729	Jan. 27	240	May 17	5.89
1971	Jan. 18	540	May 6	193	May 4	5.77
1972	Mar. 2	678	Mar. 2	271	June 6	6.26
1973	Apr. 17	166	Apr. 17	147	May 8	3.31
1974	Mar. 29	291	Mar. 29	195	May 7	4.33
Average		859		220		4.69

TABLE 4.--Monthly distribution of peak events exceeding various streamflow rates, Reynolds Creek Watershed Outlet Weir, 1963-74.

Month	Number of Events Exceeding Peak Runoff in cfs									
	200	300	400	500	600	700	900	1000	2000	3000
JAN	15	9	8	7	4	4	3	2	1	0
FEB	3	2	1	0	0	0	0	0	0	0
MAR	7	3	1	1	1	0	0	0	0	0
APR	2	1	0	0	0	0	0	0	0	0
MAY	1	1	0	0	0	0	0	0	0	0
JUNE	4	1	0	0	0	0	0	0	0	0
JULY	0	0	0	0	0	0	0	0	0	0
AUG	4	2	1	1	0	0	0	0	0	0
SEPT	0	0	0	0	0	0	0	0	0	0
OCT	0	0	0	0	0	0	0	0	0	0
NOV	0	0	0	0	0	0	0	0	0	0
DEC	3	2	2	2	2	2	2	2	1	1
Total	39	21	13	11	7	6	5	4	2	1

Bedload Transport

Samples of bedload material in transport at several Reynolds Creek locations were obtained, using a hand-held, 3-inch orifice, Helley-Smith sampler and a backhoe - mounted, 6-inch orifice, Modified Helley-Smith sampler. Data using the 3-inch sampler were more consistent and realistic because the larger sampler often could not be placed on the bottom where boulders were numerous. Results of the sediment transport studies are summarized in Table 5 and show that bedload averaged about 21 percent of the total sediment transported by Reynolds Creek on various days.

Concrete sills have been constructed at two sampling sites on Reynolds Creek to provide data for calibration of the bedload samplers when used in streams with boulder streambeds.

TABLE 5.--Summary of data from sediment transport studies, Reynolds Creek Watershed, 1974.

Station	Date	Time	Streamflow Rate	Suspended Sediment[1]	Bedload Sediment	Bedload of Total
			(cfs)	(lb./Sec.)	(lb./Sec.)	(Percent)
Reynolds Creek at Nettleton Bridge	3-15	1300	45	.294	.047	16
	4-20	1530	68	.234	.096	29
	4-22	1600	71	.245	.087	26
	4-24	1930	70	.418	.125	23
	5- 1	1400	70	.200	.015	7
	5- 1	1545	74	.166	.043	21
	5- 1	1715	81	.410	.129	24
	5- 1	1715	81	.410	.014	3
	5- 1	1820	85	.740	.106	13
	5- 5	1950	76	2.773	.653	19
	5- 7	1937	127	11.670	1.456	11
Dobson Creek	4-24	1800	25	.097	.018	16
	5- 1	1600	28	.121	.049	29
	5- 5	1840	32	.531	.457	46
	5- 7	1805	40	2.062	.493	19
East Fork of Reynolds	4-24	1650	17	.060	.022	27
	5- 1	1430	18	.170	.044	21
	5- 5	1810	21	.313	.204	39
	5- 7	1600	27	1.013	.332	25
West Fork of Reynolds	4-24	1700	24	.147	.054	27
	5- 1	1440	26	.204	.020	9
	5- 5	1800	30	1.198	.374	24
	5- 7	1645	38	3.415	.650	16
AVERAGE						21

1/ Suspended sediment transport computed by multiplying the cfs times the suspended concentration (mg/l) times 0.0000624.

Sediment yield

Yearly sediment yields from seven Reynolds Creek Watersheds are listed in Table 6 for the period of record ending in 1973. All stations show a wide range of yield from dry to wet years, depending upon runoff volume and flood occurrence. A large proportion of yearly yield was discharged during peak runoff events, as shown in Figure 2 for Reynolds Creek at Tollgate, 1967-73. Characteristically, except at the Summit, the major sediment-producing events were associated with prolonged rain, rain-on-snow, frozen or saturated soil, high humidity, and strong warm winds, which caused rapid snowmelt and peak streamflow. Table 7 shows the maximum suspended sediment concentrations, peak flow rates, and dates of occurrence at selected Reynolds Creek Watershed Stations, 1967-73.

TABLE 6.--Sediment yield from seven Reynolds Creek Watersheds, for 1965-1973

Water Year	Sediment Yield (tons/year)						
	Salmon Creek	Macks Creek	Summit Basin	Whiskey Hill	Tollgate	Upper Sheep	Reynolds Mt.
1965	---	---	---	81.17	---	---	---
1966	---	---	---	.94	---	---	---
1967	---	---	---	8.79	14675	---	23.8
1968	685	709	247	2.59	2626	---	3.7
1969	9607	7124	228	18.10	16913	---	20.5
1970	5414	4145	0	9.30	9513	1.6	37.8
1971	5732	6624	0	15.50	12836	16.2	21.6
1972	13728	6146	.7	16.90	11610	11.2	22.9
1973	1779	1373	3.4	.24	1911	14.7	11.5
Watershed Acres	8990	7846	205	119	13453	63.4	100
Tons/Acre/ Yr. Average	.685	.555	.390	.143	.744	.172	.203

TABLE 7--Yearly maximum suspended sediment concentrations, peak flow rates, and dates of occurrence at Reynolds Creek watershed stations, 1967-1973.

Water Year	WATERSHED STATION														
	Salmon Creek			Macks Creek			Reynolds Creek at Tollgate			Upper Sheep			Reynolds Mountain		
	Date	conc. mg/l	Flow cfs	Date	conc. mg/l	Flow cfs	Date	conc. mg/l	Flow cfs	Date	conc. mg/l	Flow cfs	Date	conc. mg/l	Flow cfs
1967	1-21	--	85	1-21	--	90	6-7	58,810	280	--	--	--	5-22	--	4.78
1968	2-21	20,000	33	2-21	17,850	44	2-21	8,640	189	--	--	--	8-10	--	1.48
1969	1-21	32,850	204	1-20	20,280	324	1-21	20,000	402	--	--	--	6-10	1,380	2.49
1970	1-27	16,350	210	1-27	20,300	246	1-27	5,540	237	5-2	730	0.07	5-17	650	5.89
1971	1-18	24,000	133	1-18	19,950	273	1-18	7,010	199	3-26	4,900	0.49	5-4	650	5.61
1972	1-18	38,250	201	6-9	30,000	82	3-2	8,580	267	3-2	3,500	0.75	6-6	830	6.25
1973	4-14	18,400	55	4-14	16,000	50	4-17	4,710	145	4-5	5,000	0.59	4-27	370	2.92

Erosion and sediment yield models

Procedures currently in use by action agencies for estimating erosion and sediment yield from rangeland watersheds are compared in Table 8. However, data for testing the procedures against measured yield were not available, except for the Interagency procedure. At this time the rainfall factor (R), soil-erodibility factor (K), cropping-management factor (C), coarse soil variable (X_3), soil aggregation variable (X_4), and SSF values could not be defined from watershed data. Table 9 shows a comparison of yearly sediment yield computed by the Interagency procedure and of measured values from three watersheds. Evaluation of the factors and testing of the other procedures is urgently needed.

TABLE 8.--Comparison of factors and variables in erosion and sediment yield estimating procedures.

Universal[1/] Soil-Loss Equation	Pacific Southwest[2/] Interagency Comm. Procedure	Flaxman[3/] Procedure	SSF[4/] Rating Procedure
(FACTORS)	(FACTORS)	(VARIABLES)	The rating determined from field evaluation of soil movement, surface litter, surface rock, pedestaling, rills, flow patterns, and gullies
Rainfall (R)	Climate (C) Runoff (D)	Climate (X_1)	
Soil-Erodibility (K)	Geology (A) Soils (B)	Coarse Soil (X_3) Soil Aggregation (X_4)	
Slope Length (L) Slope Gradients (S)	Topography (E)	Watershed Slope (X_2)	
Cropping-Management (C)	Ground Cover (F) Land Use (G)	None	
Erosion-Control Practice (P)	Upland Erosion (H) Channel Erosion (I)	None	

1/ Wischmeier, W. H., and D. D. Smith 1965
"Predicting Rainfall-Erosion Losses from Cropland East of the Rocky Mountains," Agricultural Handbook No. 282, Agricultural Research Service, U. S. Department of Agriculture, May.

2/ Pacific Southwest Interagency Committee 1968
"Report of the Water Management Subcommittee," October.

3/ Flaxman, Elliott M. 1972
"Predicting Sediment Yield in Western United States," Journal of the Hydraulics Division, ASCE, Vol. 98, No. HY12, December, pp 2073-2085.

4/ Bureau of Land Management 1973
"Watershed Conservation and Development System," BLM Manual, September.

TABLE 9.--Yearly sediment yield from the average of measured and estimated amounts (estimated by the Interagency procedure). Reynolds Creek and subwatersheds.

Factor Designation	Factor Values		
	Salmon Creek	Macks Creek	Reynolds Creek at Tollgate
A	3	4	5
B	2	3	4
C	2	2	1
D	3	4	5
E	10	8	10
F	- 2	- 3	- 5
G	- 3	- 3	- 2
H	3	2	2
I	10	10	9
TOTAL	28	27	29
Estimated Sediment Yield	.64	.60	.67
Average Measured Sediment Yield	.69	.56	.75

SIGNIFICANT FINDINGS

Sediment yield determinations on the Reynolds Creek Watershed show that 5 to 10 percent of yearly streamflow transports 50-90 percent of yearly sediment yield during only a few days. Sediment yield has increased about tenfold from dry to wet years in a 7-year period.

Suspended sediment concentrations usually increased with watershed size as a result of streambank erosion.

Granitic soils contribute a greater percentage of coarse material than soils of volcanic origin.

WORK PLAN FOR FY 76

Continue runoff and sediment data collection from plots and watersheds and sediment transport measurements at selected stream sites.

Test erosion and sediment yield equations and models for use on rangeland watersheds.

REPORTS AND PUBLICATIONS

Johnson, Clifton W., L. M. Cox, W. J. Rawls, G. R. Stephenson, and J. F. Zuzel 1974
Instrumentation for hydrologic research on the Reynolds Creek Experimental Watershed. Approved for publication in the proceedings of The International Water Resources Association. Presented June.

Johnson, Clifton W., G. R. Stephenson, C. L. Hanson, R. L. Engleman, and C. D. Engelbert 1974
Sediment yield from Southwest Idaho Rangeland Watersheds. Paper No. 74-2505, American Society of Agricultural Engineers Annual Winter Meeting, December.

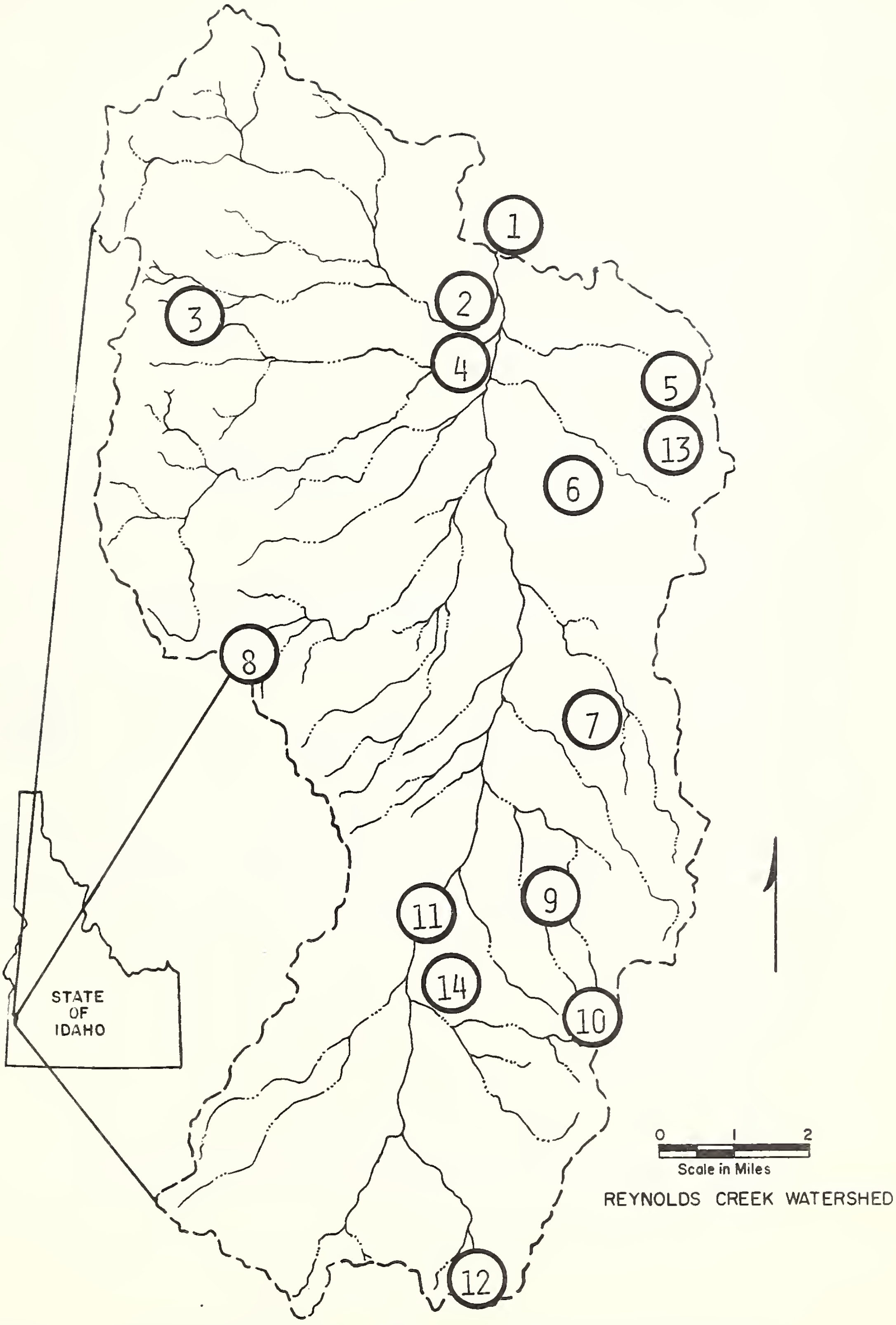

Figure 1. Locations of runoff and sediment instrumentation, Reynolds Creek Experimental Watershed, 1974.

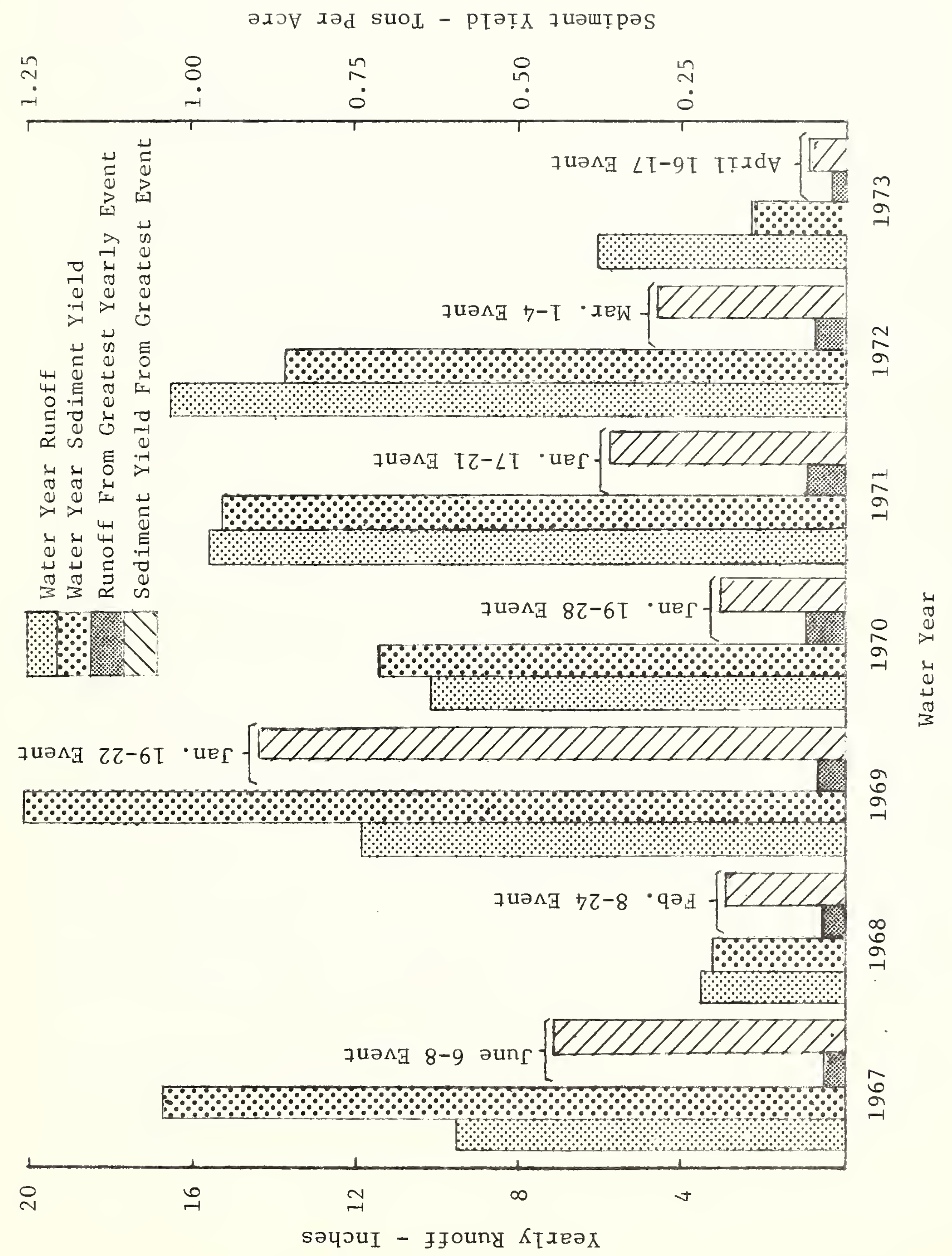

Figure 2. Yearly and greatest yearly event runoff and sediment yield, Reynolds Creek at Tollgate.

WATERSHED MODELING

Title: Developing, testing, and evaluating watershed models

Personnel Involved:

C. L. Hanson Agricultural Engineer	Coordinator and ET modeling
D. L. Brakensiek Research Hydraulic Engineer	Streamflow and infiltration modeling
G. R. Stephenson Geologist	Subsurface flow modeling
C. W. Johnson Research Hydraulic Engineer	Runoff, erosion, and sediment yield modeling
J. F. Zuzel Hydrologic Technician	Precipitation and snowmelt modeling

Date of Initiation: June 1974

Expected Termination Date: Continuing

INTRODUCTION

The development of computer hardware and software over the past decade has provided the impetus for many significant advances in the development of models that simulate hydrologic components or watershed hydrologic performance. Two philosophies appear to classify modeling as either determination or stochastic. Debate on the pros and cons of the types of models is largely irrelevant. What is important is the problem to be tackled, the quality and quantity of input data and information available, and the purpose for which hydrologic predictions are required. At the Northwest Watershed Research Center, modeling activity focuses on combining and interrelating component models, such as snowmelt, infiltration, runoff, evapotranspiration, streamflow and erosion, and sediment yield into watershed models.

The watershed models provide output data for such needs as environmental impact evaluations, water quality predictions, sediment yield modeling, storm runoff models or rangeland forage productivity.

Objectives:

1. To make a comprehensive review of existing watershed models.

2. To test existing watershed models with data from Reynolds Creek Watershed data.

3. To improve watershed model components for a sagebrush rangeland watershed, which present models do not satisfactorily represent.

4. To utilize the models to forecast the influence of land use and treatment and/or management, such as grazing systems on watershed runoff quality and quantity.

5. To apply the watershed models to other sagebrush rangeland watersheds in the Northwest.

PROGRESS

Watershed:

The modeling program at the Northwest Watershed Research Center has been progressing on two modeling efforts. The first effort is in the adaptation of a hydrologic model to the Reynolds Creek Watershed and the other is adapting a water quality model to the Reynolds Creek.

The hydrologic modeling effort is now directed toward adapting the "USDAHL-74 Revised Model of Watershed Hydrology" (Holtan, Stiltner, Henson, and Lopez, 1974) to the 205-acre Summit Basin, a subwatershed of the Reynolds Creek Experimental Watershed. This model is a modification of the "USDAHL-70 Model of Watershed Hydrology" (Holtan and Lopez, 1970) that was chosen for testing because the various model components can be individually adapted to the varying watershed conditions. The Summit Basin subwatershed was chosen because the necessary soils information is available, and it is not a snowpack runoff area. Much of the necessary input data, such as precipitation, have now been prepared for input. At the present time evapotranspiration estimates based on an evaporation pan and plant factors are being prepared.

The East Reynolds Watershed has been selected as the first watershed to model where principle runoff is from a melting snowpack.

A computer program has been developed for estimating infiltration rates with the Green and Ampt assumptions. This formulation is simple but is based on obtainable physical properties of the soil. Existing infiltrometer data can be utilized to estimate the parameter values for the Reynolds Creek Watershed.

Testing of the developed two-dimensional, transient model for subsurface flow from a melting snowdrift was concluded with 1972 data.

The water quality effort is in cooperation with the Idaho Water Resources Board and consists of using the Boise River ecologic model developed for the Corps of Engineers. Input is being prepared for Reynolds Creek as a test of the model on smaller streams. All of the necessary input except irrigation withdrawals, have been assembled for April 23 and July 16, 1974. Hopefully this model, or a modification of it, can be used to predict the water quality parameters now being measured on Reynolds Creek. The model also has the capability of giving some insight into several water quality parameters that are not now being analyzed.

An agreement has been reached with the State of Idaho computer facility (IBM 370/145) in Boise to contract for ARS use as needed. This will facilitate our watershed modeling program and progress.

Water harvesting:

A computer procedure was developed to aid in stockpond design. This procedure was demonstrated for a stockpond in western South Dakota, but the procedure can have application in many areas.

A Markov-Chain-Exponential model was employed to simulate daily precipitation amounts. A 20-year simulation, using this model, simulated the mean annual precipitation within 0.01 inch of the historical mean. Two distributions, the Exponential and the Beta, were successful in simulating daily rainfall-runoff. Snowmelt runoff was simulated on an annual basis, using an Exponential distribution. Pond water loss due to evaporation was estimated from Class A Pan evaporation. A seepage loss function developed from stockpond data in western South Dakota and eastern Montana was used to estimate daily seepage rates.

The utility of the model was demonstrated by estimating the possible reduction in pond size for a fixed watershed area and fixed cattle water demand. The cattle demand was fixed in both amount per head and the time of year when the cattle were on the watershed. The pond used in the demonstration had a low seepage rate, and, thus, the pond volume could only be reduced from 1.3 to 1.2 acre feet by lining. The volume could be reduced to 0.3 acre feet by both lining and covering the pond.

SIGNIFICANT FINDINGS

A two-dimensional, transient model was used to simulate subsurface flow from a melting snowdrift to a stream channel at the base of a slope. The results of the application of this model to 1972 data compared well with the actual field measurements. Simulation of the subsurface conditions at the piezometer nests was excellent. However, the match between the measured and simulated subsurface outflows was not as good as it was for the 1971 simulation (Stephenson and Freeze, 1974). Overall performance of this model for this particular field application was still adequate.

A computer procedure to aid in stockpond design was developed. The procedure is based on hydrologic information, contributing area, cattle numbers, length of grazing season, pond evaporation, and pond seepage. Precipitation and runoff were successfully simulated as inputs to the pond system. Special functions have been developed that describe the pond water losses. A 20-year example simulation demonstrated the utility of the computer procedures in improved stockpond design.

References:

Holtan, H. N., and N. C. Lopez 1971
USDAHL-70 Model of Watershed Hydrology, Tech. Bul. No. 1435, ARS, USDA.

Holtan, H. N., G. T. Stiltner, W. H. Henson, and N. C. Lopez 1974
USDAHL-74 Revised Model of Watershed Hydrology. Plant Physiology Inst., Report No. 4, ARS, USDA. 110 p.

WORK PLAN FOR FY 76

1. Use the procedures developed in the stockpond design program to model the effects of modifying summer thunderstorm precipitation on runoff from rangeland watersheds in western South Dakota.

2. Snowmelt forecast models will be further refined.

3. The first calibration runs of the USDAHL-74 revised model, Watershed Hydrology, will be completed on the Summit Basin.

4. Development will continue on specific input parameters to the Hydrologic Model, such as ET, infiltration, and stream routing.

5. The Boise River Ecologic Model will be run for at least two days in 1974 for Reynolds Creek.

REPORTS AND PUBLICATIONS

Freeze, R. A. 1974
Computer simulation of 1972 snowmelt event, Sheep Creek Study area, Reynolds Creek Experimental Watershed (Unpublished Termination Report).

Hanson, Clayton L., Earl L. Neff, and David A. Woolhiser
Hydrologic aspects of water harvesting in the Northern Great Plains. (In press in ARS-Western Region Publication).

Stephenson, G. R., and R. A. Freeze 1974
Mathematical simulation of subsurface flow contribution to snowmelt runoff, Reynolds Creek Watershed, Idaho. Water Resources Research 10(2): 284-294.

Zuzel, J. F., D. C. Robertson, and W. J. Rawls
Optimizing long-term streamflow forecasts. (Accepted for publication in Jour. Soil and Water Cons.)

Zuzel, J. F., and W. T. Ondrechen
A comparison of water supply forecast techniques. (Accepted for presentation at a Symposium on Watershed Management, Logan, UT).

FRAIL LAND STUDIES

Title: Hydrology of frail land watersheds

Personnel Involved:

C. W. Johnson Res. Hydr. Engin.	Perform water balance and any other analysis needed.
W. J. Rawls Hydrologist	Perform water balance and other analysis needed.

Date of Initiation: October 1968

Final Report: Submitted July 1974

INTRODUCTION

Proper management of watersheds for multiple use and protection requires a complete knowledge of the water balance with independent assessments of the water balance components. In order to determine the individual components for frail lands, a study of the hydrology of two watersheds, Rabbit Creek and Little Rabbit Creek, adjoining the Reynolds Creek Experimental Watershed, was initiated in 1968. A complete description of the watersheds and instrumentation was included in the 1968-69 water-year report.

Objective:

To determine the water balance of two frail land watersheds in the Northwest.

SUMMARY AND CONCLUSIONS

This report provides a 5-year record of hydrologic data for two range-land watersheds in Southwest Idaho. Results of the study are summarized as follows:

1. The network of dual rain gages provided data for computing "actual" precipitation based on Hamon's dual gage approach. Yearly precipitation amounts ranged from a low of 13.20 inches in 1969 to a high of 24.48 inches in 1970. Figure 1 shows an Isohyetal Map of average annual precipitation on the study watersheds for 1969-73. Also shown on this map are instrumentation sites.

2. January is the month of highest precipitation and accounts for 20 percent of annual amounts. Figure 2 shows the monthly precipitation distribution.

   A precipitation duration and intensity analysis showed that 65 percent of the yearly precipitation occurs in the October-March period. Also, the storm duration for the October-March period is longer than the April-September period. Maximum precipitation intensities occurred during the April-September period.

3. Yearly water yield per unit area from the 2360-acre watershed was 2.07 inches, which was about twice that from the 350-acre watershed. The greater percentage of drainage area at higher elevations and greater precipitation caused this difference in water yield. Figures 3 and 4 show monthly runoff distributions for the two watersheds.

4. Peak runoff rates occurred during January 1969 as a result of rain, snowmelt, and wet soils; however, no flooding or serious erosion was evident. Generally, peak runoff rates were associated with winter storms and snowmelt in January, March, and April, as shown in Table 1.

TABLE 1.--Water yield and peak discharge comparisons, Rabbit Creek Watersheds.

Water Year	Water Yield		Peak Discharge					
	Watershed 33022007 (Inches)	Watershed 33015096 (Inches)	Watershed 33022007			Watershed 33015096		
			Ft^3/Sec	csm[1/]	Date	Ft^3/Sec	csm[1/]	Date
1968-69	2.47	1.24	14.75	4.00	1-21	8.00	14.63	1-21
1969-70	.93	.47	2.07	.56	1-27	.53	.97	1-27
1970-71	2.15	.96	4.28	1.16	3-26	4.15	7.59	3-22
1971-72	3.57	1.69	7.12	1.93	3-2	2.96	5.41	1-22
1972-73	1.22	.39	2.16	.59	4-13	.43	.79	4-13
5-Year Average	2.07	.95	6.08	1.65		3.21	5.87	

1/ csm is cubic feet per second per square mile.

TABLE 2.--April to October monthly water balance for Rabbit Creek Study Basin (33022007) for 1970 through 1973

Date	Precip. (Inches)	Runoff (Inches)	Change in[1] Soil Water (Inches)	Losses[2] (Inches)	Average Daily Loss (Inches)	Date	Precip. (Inches)	Runoff (Inches)	Change in[1] Soil Water (Inches)	Losses[2] (Inches)	Average Daily Loss (Inches)
4-1-70	2.58	0.12	+1.29	1.17	0.04	4-1-72	0.64	0.53	-0.83	0.94	0.03
5-1-70	1.39	0.15	-0.73	1.97	0.06	5-1-72	0.38	0.41	-1.37	1.22	0.04
6-1-70	1.54	0.08	-1.50	2.96	0.10	6-1-72	1.58	0.19	-0.24	1.63	0.05
7-1-70	0.63	0.06	-1.00	1.57	0.05	7-1-72	0.01	0.10	-2.84	2.75	0.08
8-1-70	0.26	0.05	-1.36	1.56	0.05	8-1-72	0.44	0.07	-1.80	2.17	0.07
9-1-70	1.18	0.04	-0.62	1.76	0.05	9-1-72	1.25	0.08	+0.09	1.08	0.04
10-1-70						10-1-72					
Total for Season	7.58	0.50	-3.92	10.99	0.07		4.30	1.38	-6.99	9.79	0.06
4-1-71	1.46	0.56	-1.00	1.90	0.06	4-1-73	2.49	0.20	-0.08	2.37	0.07
5-1-71	1.14	0.43	-0.70	1.41	0.05	5-1-73	0.60	0.16	-0.72	1.16	0.04
6-1-71	2.58	0.17	-1.83	4.24	0.14	6-1-73	0.68	0.08	-1.25	1.85	0.06
7-1-71	0.78	0.10	-2.60	3.28	0.11	7-1-73	0.29	0.04	-1.49	1.74	0.06
8-1-71	0.05	0.05	-1.57	1.57	0.05	8-1-73	0.21	0.04	-1.40	1.57	0.05
9-1-71	2.34	0.04	+0.82	1.48	0.05	9-1-73	1.16	0.05	-0.25	1.36	0.04
10-1-71						10-1-73					
Total for Season	8.35	1.35	-6.88	13.88	0.09		5.43	0.57	-5.19	10.05	0.07

1/ Soil water for top 4.5 feet of soil

2/ This loss is primarily evapotranspiration during these periods; however it does include losses to groundwater

5. Runoff from thunderstorm events was not significant during the study, although intense rainfall did occur.

6. Since only a few sediment samples were collected during sediment-producing events, no sediment yield computations were made. Observations during scheduled data collection visits indicate that most sediment yield occurred during a few days of peak streamflow each year and that amounts were obviously low. Erosion condition classes were rated as stable or slight by BLM Soil Surface Factor Determinations.

7. The water balance analysis showed a maximum evapotranspiration of 0.14 inches per day in June 1971 when soil water conditions were favorable for plant growth. Monthly soil water depletion rates during the April to September period ranged from 0.03 to 0.14 inches per day, as shown in Table 2.

WORK PLAN FOR FY 76

None

REPORTS AND PUBLICATIONS

Johnson, Clifton W., and W. J. Rawls 1974
Hydrology of Rabbit Creek Watersheds, Owyhee County, Idaho, 1968-73. Pres. 29th Annual Meeting, Pacific Northwest Region, Amer. Soc. Agr. Engrs., Oct. 9-11. Paper No. 74-46.

Figure 1. Isohyetal Map of Average Annual Precipitation on the Rabbit Creek Basin for Water Years 1969-1973

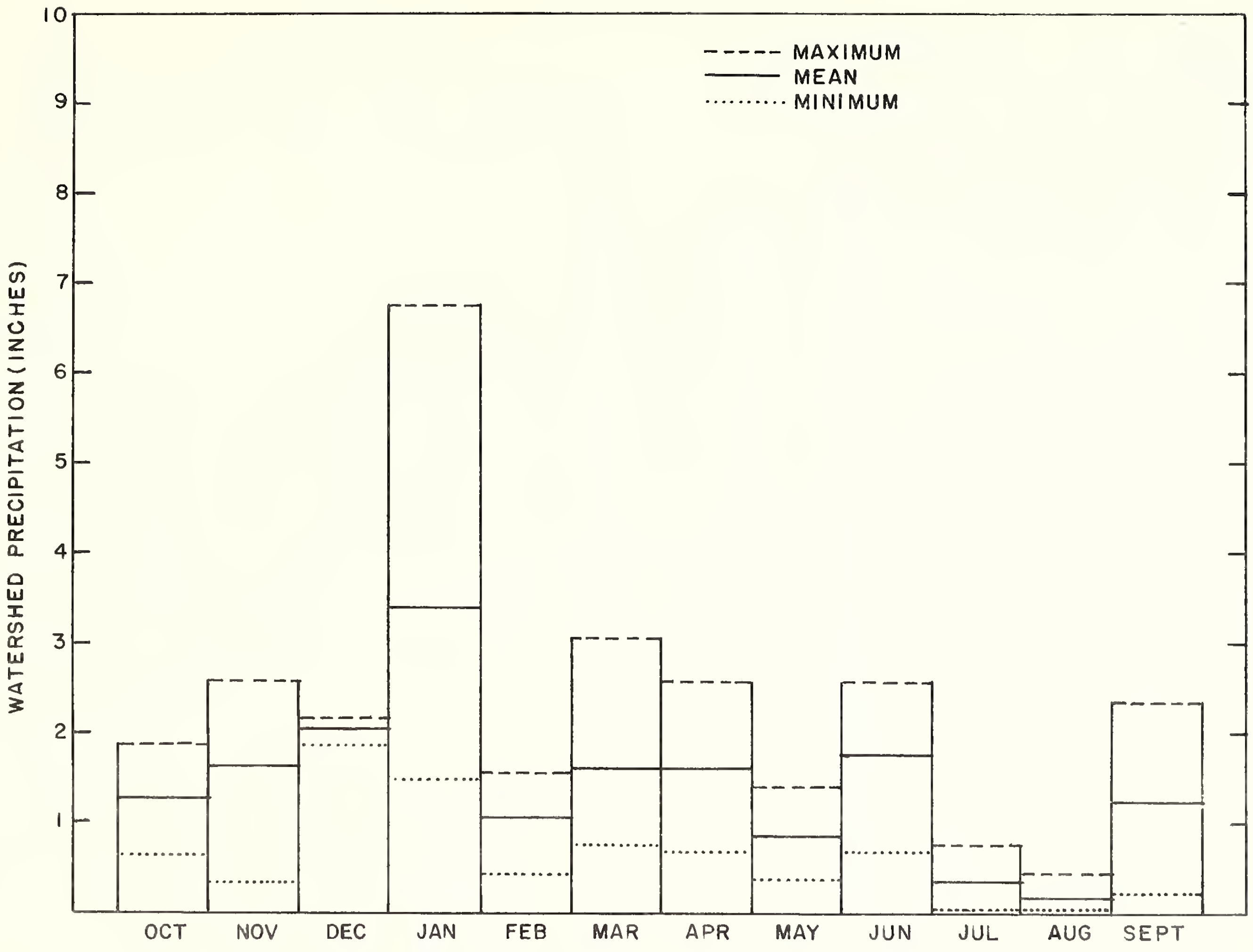

Figure 2. Monthly Distribution of Theissen Weighted Maximum, Minimum and Mean Precipitation for the Rabbit Creek Basin for Water Years 1969-1973

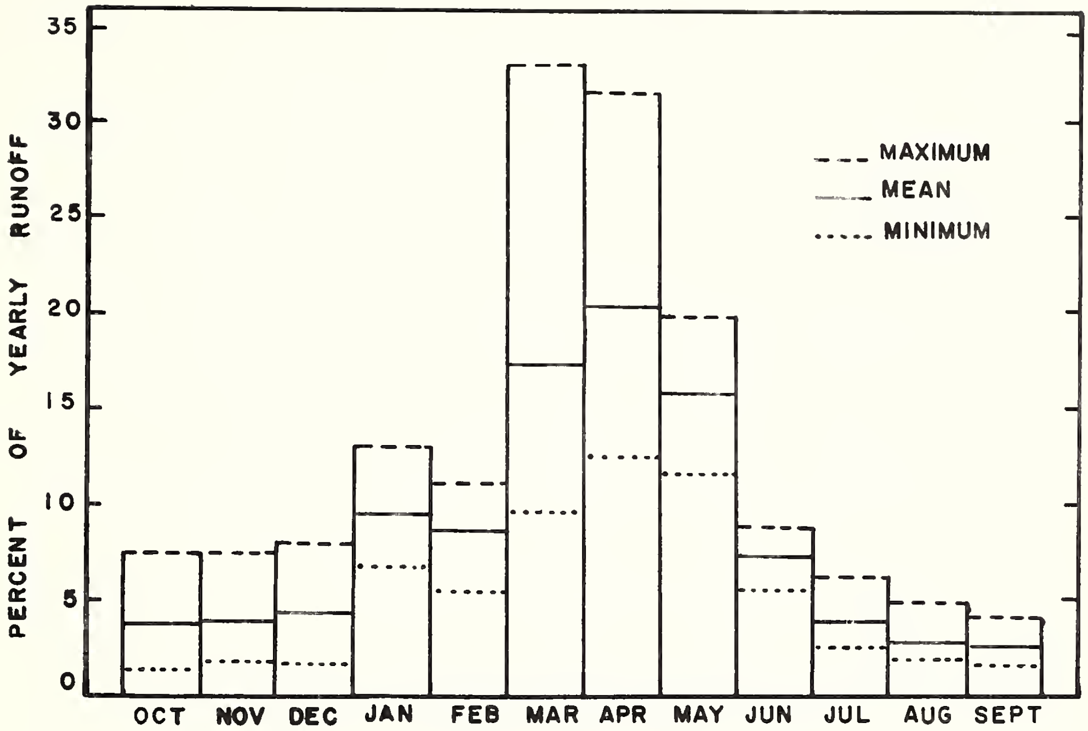

Figure 3. Monthly Runoff Distribution, 5-Year Record on 2360-Acre Watershed, Rabbit Creek

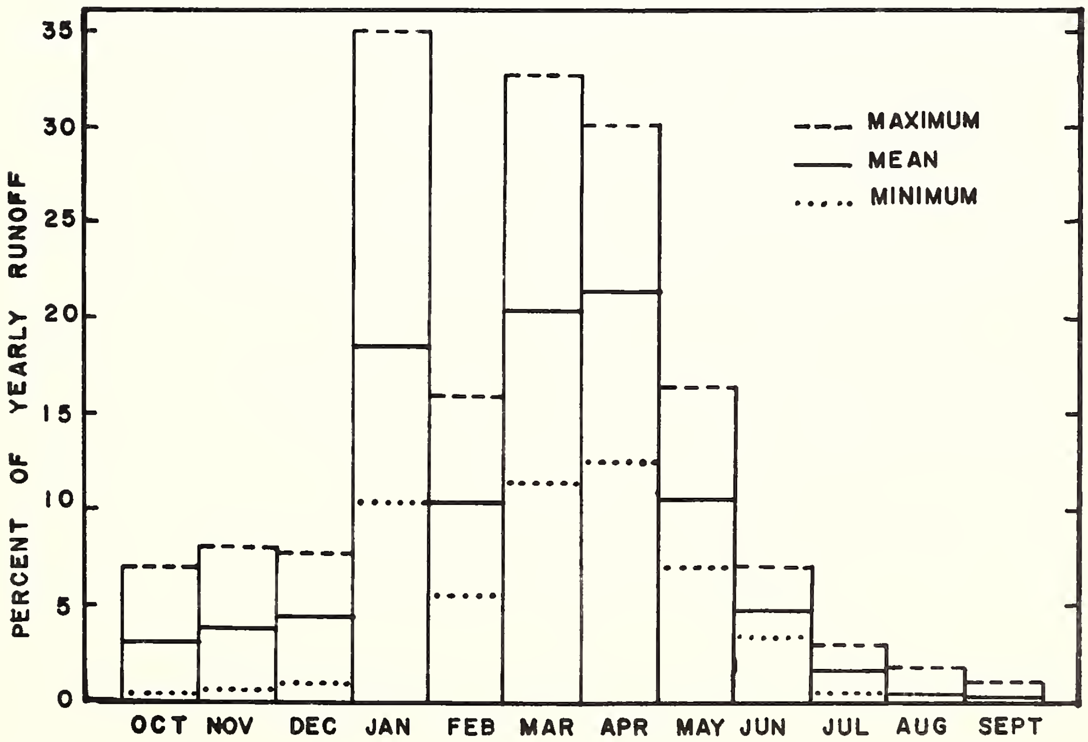

Figure 4. Monthly Runoff Distribution, 5-Year Record on 350-Acre Watershed, Rabbit Creek

A P P E N D I X

RESEARCH RESULTS FROM ARS RANGE RESEARCH AT COTTONWOOD, SOUTH DAKOTA

Clayton L. Hanson

10-Year Summary:

The basic information for a summary of a 10-year study, 1963 through 1972, designed to determine how three grazing levels affect western South Dakota rangeland hydrology, was completed.

The study was located on the Cottonwood Range Field Station, Cottonwood, SD. The Field Station is a substation of the South Dakota Agricultural Experiment Station.

Four 2-acre watersheds were established on each of three pastures that had been grazed heavily, moderately, or lightly during the summers from 1942-1967, resulting in a low, medium, and high range condition.

The pastures were ungrazed in 1968, and were grazed for maximum livestock production without changing the range condition from 1969 through 1972.

Vegetation:

Average percent basal cover is listed in Table 1. Short grasses make up the highest cover percentages on all watersheds varying from 76 percent on the low to 31 percent on the high range condition watersheds. Midgrasses account for only 1 percent of the basal cover on the low and 26 percent on the high range condition watersheds. Forbs account for 1 to 5 percent of the basal cover on all watersheds. Mulch, rock, and bare ground account for 22, 27, and 38 percent of the basal cover on the low, medium, and high range condition watersheds, respectively. The various cover percentages on each watershed varied considerably between years. All watersheds had the least live vegetal basal cover in 1966, when the months of April through July were very dry.

Mean over-dry weights of grasses, forbs, and mulch are displayed in Table 2. Mean weights of grasses, which include sedges and annual bromes, were 553, 499, and 698 pounds per acre from the low, medium, and high range condition watersheds, respectively. The total vegetal weights were 1844, 2008, and 3338 pounds per acre. The grasses and total cover weights were significantly greater from the high range condition watersheds than from the other treatments. The low range condition watersheds had the least midgrasses, forbs, and mulch cover, and the high range condition watersheds had the highest cover of midgrasses, forbs, and mulch.

The annual live vegetal weights varied considerably between years, with the lowest weights on all treatments in 1966. The highest weights from all treatments were in 1965 when there was about 10 inches of precipitation in the May through June period and following a year when there was about the same amount of rain during this same period.

Annual Runoff:

The mean annual runoff was 0.91, 0.77, and 0.59 of an inch from the watersheds in low, medium, and high range conditions, respectively (Table 3). An analysis of variance shows that the mean annual runoff between the watersheds in high and low range conditions differed significantly ($P < .05$), with the most runoff from the low and the least runoff from the high range condition watersheds.

The greatest annual runoff was from the low range condition watersheds when there was 1.79 inches of runoff due to the rainfall in 1963. Annual runoff exceeded one inch during each of four years from the low range condition, four years from the medium range condition, and two years from the high range condition watersheds. The least runoff was in 1970 when there was 0.06 of an inch or less annual runoff from any of the watersheds.

The months of March, May, and June account for most of the runoff from any of the watersheds. The March runoff is normally from snowmelt and the runoff during May and June is summertime thunderstorms, but there was considerable runoff in 1964 and 1965 in May, from snowmelt runoff.

Summer Season Runoff (May 14-October 31):

The summer season is considered from May 14 through October 31, because this is the period when there was no runoff due to snowmelt. The average seasonal runoff was 0.55, 0.38, and 0.26 of an inch from the low, medium, and high range condition watersheds, respectively (Table 3). Runoff was the greatest in 1963 when the low range condition watersheds produced 1.79 inches, and the least was in 1970, when there was no runoff during the summer season from any of the watersheds. The low range condition watersheds had the most runoff eight out of the ten years. In 1965 the middle watersheds yielded the most runoff, but the difference among the three watersheds was only 0.02 inch. In 1972 the high range condition watershed actually yielded the most runoff, but the difference again between all of the watersheds was only 0.03 inch. The high range condition watersheds yielded the least runoff 8 of the 10 years.

The effect of the different grazing intensities can also be demonstrated in the number of runoff events during the months of July, August, September, and October. On the heavily used watersheds, there was significant runoff in July, some in August, September, and October. From the medium range condition watersheds there were two small events in July, one in August, and one in October; whereas, from the high range condition watersheds there was one small runoff event in July, and none in August, September, or October.

For the ten summer seasons, there were 35, 26, and 21 runoff events with 0.01 inch or greater from the low, medium, and high range condition watersheds, respectively. The data indicate that this difference is because runoff on the low condition watersheds comes from short, intense storms as well as from long-duration storms. The data also suggests that the runoff from the long-duration storms may be as much from the watersheds in high range condition as from the other watersheds, especially when the storm follows a wet period.

Peak runoff rates, as effected by grazing intensities, are also very different between watersheds. The low range condition watersheds had the highest runoff rate and the high range condition watersheds the lowest rates. The maximum rates recorded were 3.89, 1.65, and 0.50 inches per hour from the low, medium, and high range condition watersheds, respectively. These maximum rates were all recorded during 1963 when there were two 3-inch rains within 16 days of each other. The low range condition watersheds had seven runoff events above 0.5 inches per hour while the medium had only one and the high range condition only equalled this value once.

Snowmelt Runoff:

About half the average annual runoff was during January through the first thirteen days of May. Not all of the runoff in April and the first part of May was due to snowmelt, but the big share of it was either snowmelt or snow and rain mixed. In 1967, the only runoff during May was from snowmelt.

There was snowmelt runoff in March and April, 1966; January, March, and May of 1967; March of 1969; January, February, March, and April of 1971; and January and February of 1972. There was also some snowmelt runoff during 1964 and 1970. The only runoff for 1970 was from snowmelt and averaged about 0.03 inch. Snowmelt runoff during 1966, 1967, 1969, and 1971 caused the big difference between the annual and seasonal runoff. Snowmelt runoff during March was the greatest for any of the months.

The snowmelt runoff from the high range condition watersheds was about as much as from the other watersheds. This is most likely because the vegetation on these watersheds holds a uniform snow cover, whereas on the other watersheds there were drifts and some areas with very little snow cover.

Significant Findings:

The studies at Cottonwood, SD, show that past grazing treatments, resulting in different range condition categories, have affected the runoff regime of the watersheds, with those watersheds in low range condition producing the greatest runoff and those in high condition producing the least.

TABLE 1.--Average percent basal cover, 1963 and 1965 through 1972.

Cover	WATERSHEDS		
	Low Range Condition[1/]	Medium Range Condition	High Range Condition
Midgrasses	1	15	26
Short grasses	76	53	31
Forbs	1	5	5
Mulch, Rock, Bare	22	27	38

1/ Averaged from four watersheds and 125 points per watershed.

TABLE 2.--Average vegetal weight (lbs/acre, oven-dry) in late July, 1963 through 1972.

Watersheds	Grasses			Forbs	Mulch	Total Cover
	Mid	Short	Total			
Low Range Condition	9	544	553[a1/]	21	1270	1844[a]
Medium Range Condition	114	385	499[a]	68	1441	2008[a]
High Range Condition	404	294	698[b]	161	2479	3338[b]

1/ Means with the same superscript are not statistically different from each other at the 0.05 level of significance.

TABLE 3.--Annual and summer (May 14-October 15) runoff, 1963-1972.

Year	Watershed					
	Low Range Condition		Medium Range Condition		High Range Condition	
	Annual	Summer	Annual	Summer	Annual	Summer
1963	1.79	1.79	1.59	1.59	1.17	1.17
1964	.68	.66	.28	.28	.05	.05
1965	.13	.13	.14	.14	.12	.12
1966	1.66	.16	1.36	.01	1.51	.00
1967	1.42	1.21	.81	.79	.62	.54
1968	.40	.40	.20	.20	.02	.02
1969	1.22	.32	1.16	.07	.75	.03
1970	.03	.00	.06	.00	.01	.00
1971	.88	.20	1.24	.14	.88	.09
1972	.81	.58	.88	.56	.84	.59
	.91[a] [1/]	.55[1]	.77[a,b]	.38[1,2]	.59[b]	.26[2]

1/ Means with the same superscripts are not significantly different from each other at the 0.05 level of significance.